APPENDIX A-2

Analysis to Support Suitability Determination of Dredged Material with Polychlorinated Dibenzo-*p*-dioxins and Furans for Disposal at the Anderson-Ketron Dredged Material Disposal Site

Puget Sound Dredged Material Management Program

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1. Purpose and Background

1.1. Purpose

This memo presents an analysis used by the DMMP agencies to develop an interim interpretive guideline for polychlorinated dibenzodioxins and furans (PCDD/F) in dredged material proposed for disposal at the Anderson-Ketron open water site (A/K site). Specifically, the analysis performed includes (1) an overview of the background on this analysis; (2) a description of the A/K site and dioxin data collected at the site and other urban and non-urban areas in Puget Sound; (3) development of a site conceptual model for PCDD/F exposure in the Nisqually Reach area in which the A/K site is located; (4) estimation of a range of risk-based concentrations in bottom fish and crabs associated with an upper-end tribal exposure scenario; (5) relating risk-based concentrations to modeled tissue concentrations in the same species (using site sediment data) and (6) development of an interim, disposal-site-specific interpretation framework and guidelines for sediment PCDD/F based on maintaining the non-urban background PCDD/F concentrations that currently exist at the A/K site and surrounding sediment.

This analysis is a risk-based screening procedure, and is not intended as a baseline risk assessment for the A/K site. A baseline risk assessment is a concept used in cleanup programs to disclose the summary risk to human and ecological receptors for a large number of site chemicals. A risk screen typically focuses on selected aspects (a single compound or compound suite such as PCDD/F, or a particular group of organisms or human receptors). An example of the application of a risk-based screen to establish a site-specific guideline, occurred for PCBs associated with the Elliott Bay Disposal Site (DMMP, 1999). In the current case, the DMMP agencies needed to determine, within the short time frame of a pending dredging project, whether risk-based interpretive criteria (specifically, a bioaccumulation trigger, BT [1], and target tissue level, TTL [2], for PCDD/F) could be developed for the A/K site using available information. The DMMP agencies do not intend that either the interim guidelines for Anderson-Ketron Disposal site or the approach used to derive it should be applied programmatically until the analysis methodology has received broad scientific and stakeholder review. As such, the DMMP agencies will hold a meeting (or meetings) to discuss risk-based versus site-chemistry-based approaches to setting programmatic guidelines for PCDD/F at open water disposal sites in Puget Sound.

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[1] BTs are sediment values above which bedded bioaccumulation testing is required using two benthic marine species. BTs may be based on experience or predicted tissue concentration, and are usually developed after TTLs at this time.

[2] TTLs are the measurement endpoints (not-to-exceed tissue concentrations in the two benthic marine test species) associated with an adverse effect; for instance, when a TTL is exceeded, in the benthic bioaccumulation test, then an unacceptable consequence such as a human health or ecological risk is predicted to occur.

1.2. Background

This effort to develop a site-specific interpretive guideline for PCDD/F was triggered by a project-specific proposal (by the Corps and the Port of Olympia), to dispose of dredged material from two berths and the navigation channel in Budd Inlet at the DMMP's Anderson/Ketron (A/K) open water disposal site. The project sediments are located in close proximity to the Cascade Pole Model Toxics Control Act (MTCA) site, which was a known historic source of PCDD/F contamination in Budd Inlet. The Anderson-Ketron disposal site is located in a non-urbanized South Puget Sound area utilized for commercial and subsistence fishing by a tribal population. The selection of the A/K site was originally made by the DMMP (then called PSDDA) agencies due to the deep water and relatively low site utilization by benthos, fish, and crabs. (Section 2 further describes the site.)

PCCD/F have long been acknowledged by the DMMP to be contaminants of concern based on their high toxicity (carcinogenicity) and propensity to bioaccumulate and bioconcentrate. The Evaluation Procedures Technical Appendix (PSDDA, 1988) recommended that PCDD/Fs not be included as chemicals of routine concern for analysis in sediments, but instead be designated "special" chemicals of concern with limited application. The "special areas" designation was due in part to the expense involved for testing for these compounds as well as their expected limited distribution within Puget Sound. In recent DMMP clarifications and program developments (DMMP, 2003), PCDD/F were included on the DMMP revised bioaccumulative contaminants of concern (BCOC) "List 1" (contaminants required for analysis in all tested dredged material), but it was stated that this would only be required of projects for which there was a reason to believe that sediments may contain PCDD/F (e.g., located near specific sources of current/historical PCDD/F, such as chlor-oxide bleach process pulp mills, chlor-alkali or chlorinated solvent manufacturing plants, or former wood treatment sites). Since 1990 only four Puget Sound projects have been required to test for dioxins. Likewise, PCDD/F analysis has not been included in routine disposal site monitoring. Limited testing for dioxin has been performed by the DMMP at the Elliott Bay, Anderson-Ketron and Port Gardener disposal sites. (The latter two data collections were in response to the circumstances which have generated this memo.)

To date, the DMMP has not established programmatic TTLs or BTs for PCDD/F. Figure 1 (page following) outlines the approach that has been used until recently to determine suitability of dredged material containing PCDD/F. The User's Manual indicates that 15 ng/kg TEQ (or 5 ng/kg of 2,3,7,8-TCDD) be considered to determine the need for bioaccumulation testing. However, these values were derived from human health risk assessments conducted in 1989-1991 for Grays Harbor. Specifically, the risk assessments applied to

oceanic and estuarine disposal sites and considered recreational fisher's exposure (PTI 1990, Shapiro 1991). The hydrographic conditions at the disposal sites and assumed human exposure are very different from that which would be applied to Puget Sound disposal sites. After revisiting the basis for the Grays Harbor guidelines, the DMMP agencies concluded that the process used in Grays Harbor is inappropriate to estimate exposure and risk for Puget Sound fishing populations, which includes native subsistence seafood harvesters.

In accordance with program goals, development of new interpretive guidelines for dredged material suitability should include the best available information for the disposal site and surrounding area as well as an evaluation of risk for highly exposed populations. In addition, there should be an opportunity for stakeholders and potentially affected public to comment and provide input to the process. However, given that the DMMP agencies had a short time frame for the suitability decision for the Port of Olympia sediments, it was decided that a risk screen instead of a complete baseline risk assessment (such as that used for remedial decision-making for Superfund or MTCA sites) using available data could be used to develop an interim guideline for A/K site. The approach developed for the A/K site may serve as a starting point for public and stakeholder discussion in developing a DMMP process for a programmatic revision to address PCDD/F. The agencies ultimately expect to present an agreed-upon approach to setting limits for dioxin at both dispersive and non-dispersive sites at the 2007 Sediment Management Annual Review Meeting.

Figure 1

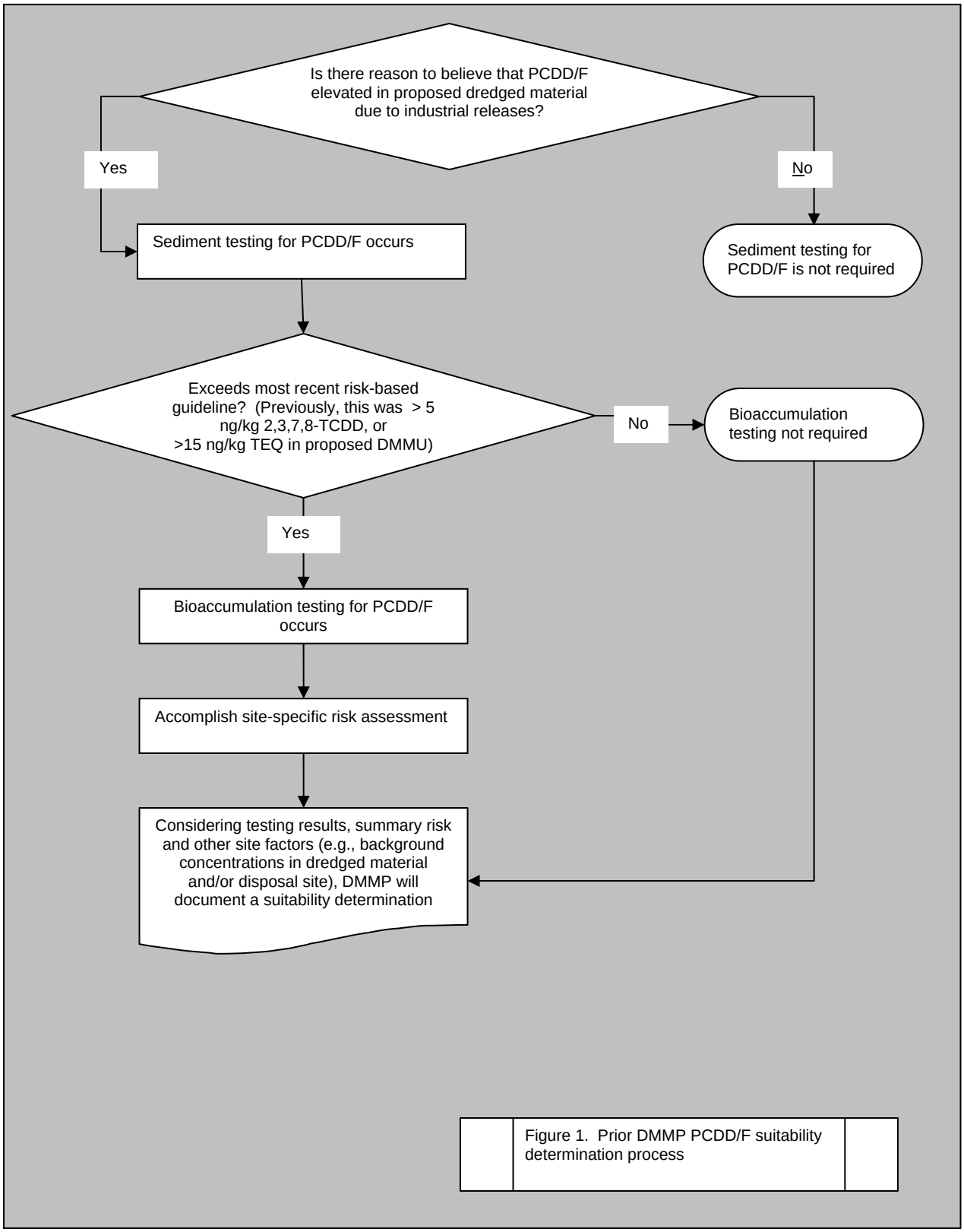

Figure 1. Prior DMMP PCDD/F suitability determination process

2. Anderson-Ketron Disposal Site

2.1 Site Description

The Anderson-Ketron disposal site is located in southern Puget Sound, situated between Anderson and Ketron islands, and southwest of Steilacoom (see Figure 2). The disposal site encompasses 318 acres and is located in a relatively flat non-dispersive area with an average depth of approximately 440 ft. The site has received 32,826 cy of dredged material since 1989; this is considered low use compared to other disposal sites. The site management program to date has included 1 baseline and 1 full monitoring event.

2.2 PCDD/Fs at the Anderson-Ketron Site

As part of the DMMP's 2005 A/K site monitoring event, the DMMP took the unusual step of analyzing archived sediments and benthic infaunal tissue for PCDD/Fs using EPA method 1613B for 2,3,7,8-substituted chlorinated dioxins and furans[3]. The following eight sediment samples were analyzed:

- Sediment from onsite station, AKZ01 (0-10 cm interval)
- Sediment from transect station, AKT01 (0-10 cm interval)
- Sediment from four perimeter stations AKP01,-02,-03,-04 (0-2 cm interval)[4]
- Sediment from two benchmark stations AKB02 & 03 (0-2 cm interval)

Benthic tissue was collected representing three bivalve species (*Yoldia*, *Compsomyax,* and *Macoma*). Although benthic infaunal tissue was archived at all transect and benchmark stations, there was not sufficient tissue mass to perform dioxin/furan analysis and also measure lipid concentrations at all locations. PCDD/F and lipid analyses was performed on tissue from the following sampling stations where sufficient bivalve tissue was archived:

- One sample of *Yoldia* from transect station AKT01
- Three *Compsomyax* samples from the benchmark stations AKB02, AKB03 and the transact station AKT01.
- One *Macoma* sample from benchmark station AKB03.

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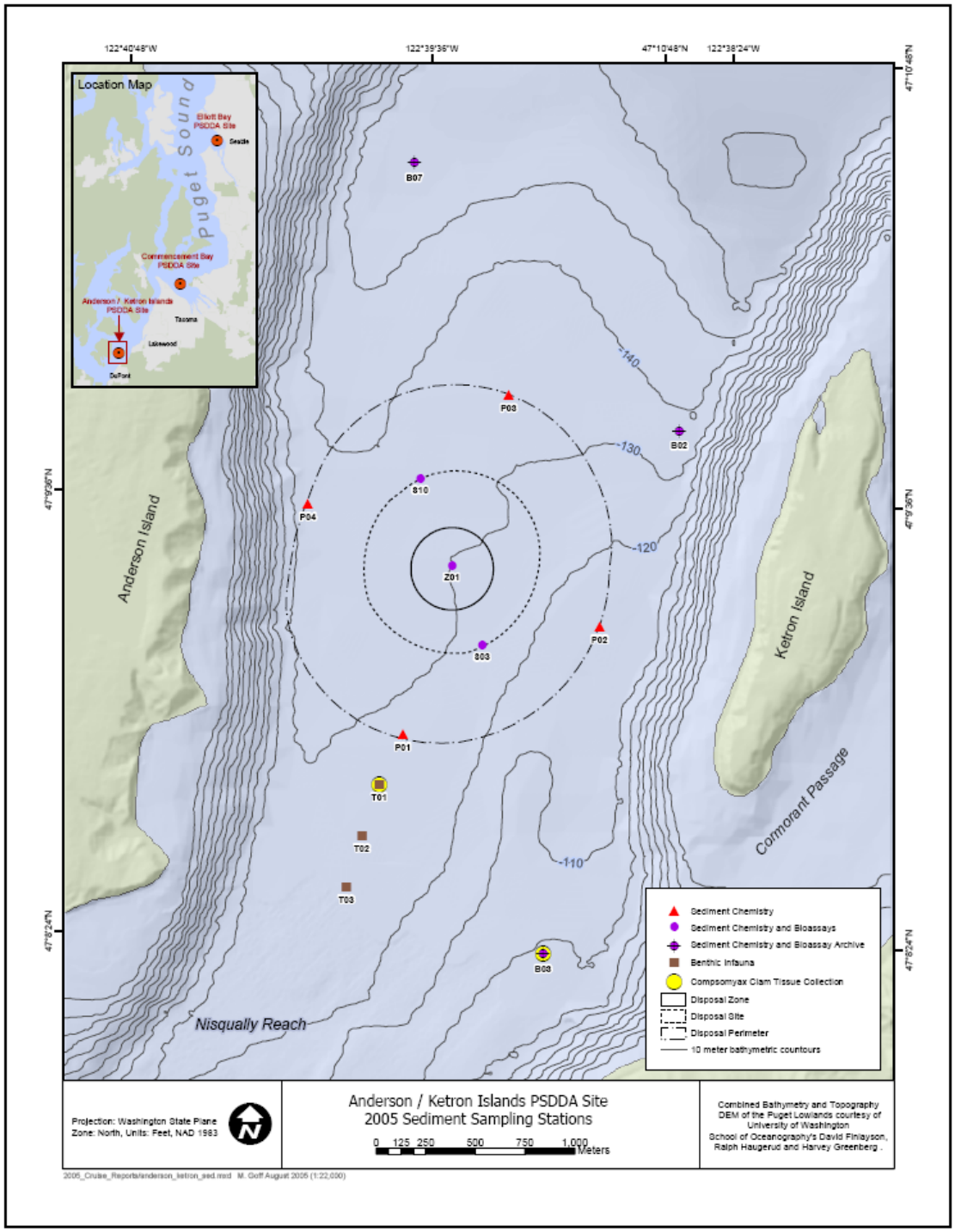
[3] Prior to 2005, PCDD/Fs were not a routine suite of chemicals for analysis during disposal site monitoring. In 2005, PCDD/F analysis was included for a subset of onsite sediments at the Elliott Bay disposal site. Dioxin data collected in tissues and sediments as part of the 2006 monitoring of the Port Gardener disposal site will be available in Fall 2006.

[4] The DMMPs standard monitoring procedures dictate that perimeter and benchmark samples are collected from the 0-2 cm interval to characterize recently deposited material and thereby assess an influence of site related disposal on adjacent offsite areas.

Figure 2. The Anderson-Ketron Disposal Site



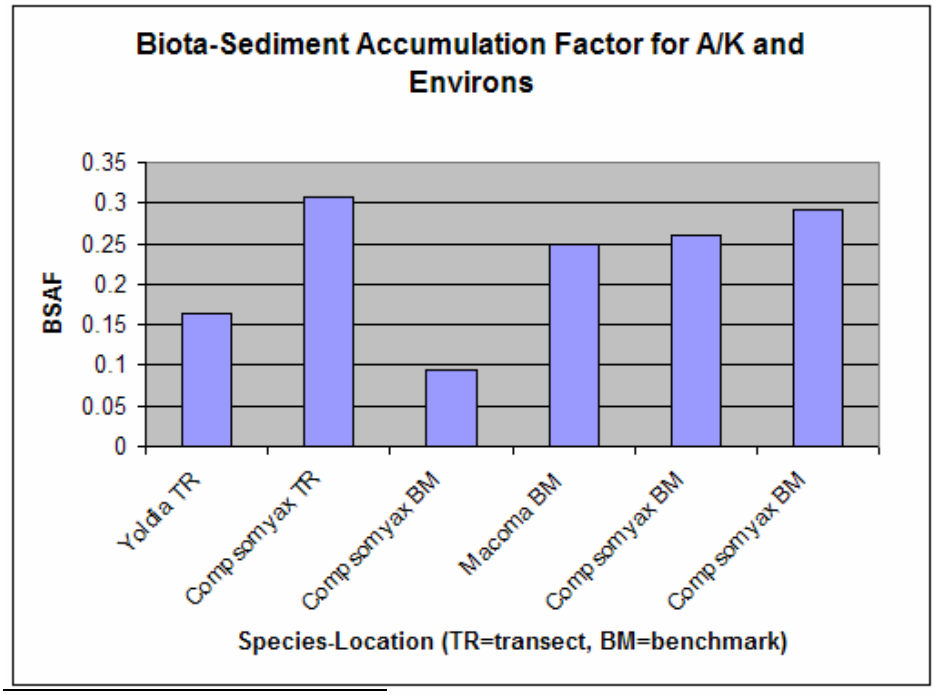
The results of these analyses are presented in Tables 1 and 2. The range of sediment concentrations of PCDD/F expressed in 2,3,7,8-tetrachloro-*p*-dibenzodioxin toxicity equivalent concentrations TEQ[5] in the eight sediment samples analyzed was 1.8 – 7.3 ng/kg dry weight and the mean was 3.8 ng/kg dry weight. The range of tissue PCDD/F in the five bivalve samples tested was 0.05 – 0.53 ng/kg dry weight. The range of lipid in these samples was 0.08 – 1.32% (wet weight) with an overall (across-species) average of 0.4%.

2.3 Interpretation of A/K PCDD/F data

Based on a qualitative evaluation, there are no apparent trends in PCDD/F concentrations among the A/K onsite, perimeter, transect, and benchmark stations in either the sediment or tissue data. The small number of samples, however, limits statistical comparisons among stations.

Biota-sediment accumulation factors (BSAF) indicate the ability of benthos to assimilate compounds from the sediment. (The BSAF equations are described in Appendix E.) As represented by the bivalves at the A/K site, the BSAFs range from slightly less than 0.1 to slightly more than 0.3 (see Figure 3).

Figure 3. PCDD/F TEQ Biota-Sediment Accumulation Factors for A/K and Environs



[5] PCDD/F data presented here is expressed as a toxic equivalency quotient (TEQ) using ½ detection for non-detected congeners and the International Toxic Equivalency Factors (I-TEF) (Van den Berg et al. 1998). Another method has been used historically, namely the 1989 TEFs. Where possible, we have used the 1998 I-TEFs.

2.3.1 Potential sources of PCDD/F to the A/K site

There are no known anthropogenic point sources of PCDD/F to the A/K site although Fort Lewis' waste water treatment plant discharge at Tatsolo point is less than a kilometer south of the baseline site B03. Nonpoint sources may include atmospheric deposition and currents in Puget Sound.

Since its first use 13 years ago, the A/K site has received 32,826 CY of dredged material from the following projects in rank order of their volumetric contribution:

- Indian Cove Maintenance, Hartstene Island (1995), 8,677 CY
- Washington Department of Transportation, native sediment from Tacoma Narrows (2005), 8,180 CY
- Day Island Yacht Club, Tacoma Narrows (1993), 6597 CY
- Olympia Yacht Club (2004), south end of Budd Inlet, 5772 CY
- Lott Sewage Treatment Plant, excavation for outfall NW of peninsula (1993), 3,600 CY.

The dredged material disposed at the A/K site in the past has largely been from small marinas and from project such as the Tacoma Narrows bridge construction which involved dredging of glacial till. Sediments from two of the projects (Olympia Yacht club and the Lott outfall) may have contained PCDD/F, given their location within Budd Inlet. However, since PCDD/Fs were not included in the analyte lists for these projects, there are no data to estimate the magnitude of PCDD/F in these sediments. The lack of an onsite-to-offsite trend of PCDD/F at the A/K site could mean that, had PCDD/F been present, the 1993 and 2004 events' sediments have been buried under the 2005 event sediments. Although a number of the 0-2 cm samples might not have seen buried horizons, PCDD/F in the 0-10 cm (AKZ01 and AKT01) are within the range of the 0-2 cm samples.

2.3.2 Review of available data on urban and non-urban background sediment PCDD/F

The role of background in the DMMP is to assess significance of effect; for instance, reference sediments from un-impacted areas of Puget Sound are used as comparison treatments when conducting toxicity testing on project sediments. For bioaccumulation, tissue chemistry is compared both to a target tissue level (TTL), as well as to bioaccumulation potential from exposure to Puget Sound reference area sediment. In what follows, sediment concentrations representing background conditions are discussed to the extent that they are known, but there is no programmatic intent to assign a level of effect to a sediment chemistry value. Instead, the objective of this discussion is understand the relationship of the A/K site to other Puget Sound "background" sites in terms of sediment chemistry.

Nearly all of the existing data on background sediment concentrations of PCDD/F in Puget Sound have been generated as part of remedial investigations or Natural Resource Damage Assessment involving dioxins and furans (e.g., Olympic View Resource Area, Pacific Sound Resources, and Cascade Pole,). These studies sampled 19 background stations in Commencement Bay, Elliott Bay and Budd Inlet. Station locations within these water bodies were chosen to be proximal to diffuse urban sources of PCDD/Fs but outside the influence of the remedial site in question. The PCDD/F data from the Commencement and Elliott Bays sampling range from 0.18 – 35.07 ng/kg TEQ and represent background in an aquatic environment influenced by general non-point sources draining a large, highly urbanized area with historic wood-treatment and other industrial processes such as (for Commencement Bay) chlorinated solvent and alkali production. The PCDD/F area data from Budd Inlet (0.51 - 54 ng/kg TEQ) are from a less urban area, but their independence from the influence of the Cascade Pole site has recently come into question (R. McMillan, pers. comm.).[6] Additional data on urban background PCDD/F have recently been collected for the Lower Duwamish Superfund site. In this study, 13 samples were collected from 9 locations in the greater Seattle area in order to characterize sediment PCDD/Fs proximal to potential non-point sources and draining urbanized areas similar in size and nature to that influencing the Lower Duwamish River. (This information is still under agency review and is, for that reason, not summarized here.)

Dioxin data have also been collected by the DMMP agencies at the Elliott Bay disposal site in 2005. Sediments were collected from 3 onsite locations and measured PCDD/Fs ranged from 0.7 – 6.6 ng/kg TEQ. There are no other DMMP sites for which dioxin data is currently available.

In contrast to urban environments, there are few data available that characterize PCDD/Fs in sediments from non-urban background locations (e.g., Puget Sound reference sites). A single sample collected from Yukon Harbor (the background sample for the Manchester Annex cleanup) is reported to be 0.72 ng/kg TEQ.[7] NOAA collected and analyzed a sample from the Carr Inlet reference area (unpublished data from the NRDA settlement in Commencement Bay [8]), and reported a total TEQ concentration of 0.3 ng/kg. While the DMMP has recently submitted several samples from Carr Inlet for dioxin analysis (as part of the Port Gardiner monitoring effort), these data are not available at this writing.

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[6] The range of this data reflect TEQs recalculated using the 1998 I-TEFs at 0.5 * DL for nondetected values.

[7] Calculated TEQs were based on 0.5 * DL for nondetected values; TEFs used were the 1989 values. The TEQ was not recalculated for the current report as the original data were not readily available.

[8] Marla Steinhoff, NOAA, personal communication (2005). These data have until recently been privileged and confidential, but have lately been approved for release.

2.3.3 Comparison of A/K sediment PCDD/F data to background

The range of PCDD/F in A/K sediments (1.8 – 7.2 ng/kg TEQ) falls within the lower end of the range of values measured in stations representing urban background and is higher than the two available data points that we have located to represent non-urban background. However, this begs the question of what is an appropriate point of comparison with which to evaluate this disposal site. The A/K site is not located near an urban center, and are there no known urban or industrial sources for PCDD/Fs in the nearby drainage. Thus, while comparison to data from a non-urban area is believed to be more appropriate in order to ascertain whether the sediment dioxin concentrations observed at and around the A/K site are elevated over what would be expected, sufficient data from reference or background areas in south Puget Sound are lacking at this time. The DMMP is continuing to search the available literature and data bases in order to compile any existing PCDD/F data that would represent non-urban background. This information will be useful for interpreting future data from disposal site monitoring as well as in deliberations on comparisons to urban versus non-urban PCDD/F background.

2.3.4 Summary of A/K site sediment comparison

There are insufficient data (urban and non-urban) to meaningfully compare A/K site data against. Based on current information, the agencies believe that the A/K site PCDD/F profile in the biologically-active zone has not been significantly altered by the placement of dredged material. The lack of a trend in PCDD/Fs away from the A/K site suggests that these values provide a suitable estimate of local-area PCDD/F background in sediment.

Table 1. Ketron Island Tissue Results for PCDD/F

Analyte	TEF	AKT01 - Yoldia			AKB02 - Compsomyax			AKB03 - Macoma			AKT01 - Compsomyax			AKT01 - Compsomyax			AKB03 - Compsomyax		
		ng/kg-ww	LQ	TEQ	ng/kg-ww	LQ	TEQ	ng/kg-ww	LQ	TEQ	ng/kg-ww	LQ	TEQ	ng/kg-ww	LQ	TEQ	ng/kg-ww	LQ	TEQ
2,3,7,8-TCDD	1	0.031	U	0.0155	0.044	U	0.022	0.035	U	0.0175	0.021	U	0.0105	0.029	U	0.0145	0.017	U	0.0085
1,2,3,7,8-PeCDD	1	**0.121**	J	0.0605	0.077	U	0.0385	0.058	U	0.029	0.03	U	0.015	0.035	U	0.0175	0.048	U	0.024
1,2,3,4,7,8-HxCDD	0.1	0.332	U	0.0166	0.094	U	0.0094	0.091	U	0.00455	0.026	U	0.0013	0.051	U	0.00255	0.041	U	0.00205
1,2,3,6,7,8-HxCDD	0.1	**0.524**		0.0524	0.092	U	0.0046	**0.166**	J	0.0166	0.027	U	0.00135	0.052	U	0.0026	0.041	U	0.00205
1,2,3,7,8,9-HxCDD	0.1	**0.215**	J	0.0215	0.09	U	0.0045	**0.097**	J	0.0097	0.026	U	0.0013	0.05	U	0.0025	0.039	U	0.00195
1,2,3,4,6,7,8-HpCDD	0.01	**4.67**		0.0467	**0.96**	J	0.0096	**1.65**		0.0165	**0.282**	J	0.00282	**0.271**	J	0.00271	**0.275**	J	0.00275
OCDD	0.0001	**24.1**	B	0.00241	**6.31**		0.000631	**11.9**		0.00119	**2.2**		0.00022	**2.07**		0.000207	**2.01**		0.000201
2.3.7.8-TCDF	0.1	**0.496**		0.0496	**0.119**	JN	0.0119	**0.103**	JN	0.0103	**0.036**	JN	0.0036	**0.03**	JN	0.003	**0.036**	JN	0.0036
1,2,3,7,8-PeCDF	0.05	**0.283**	J	0.01415	0.092	U	0.0023	**0.055**	J	0.00275	0.03	U	0.00075	0.049	U	0.001225	0.057	U	0.001425
2,3,4,7,8-PeCDF	0.5	**0.32**	J	0.16	0.093	U	0.02325	0.06	U	0.015	0.03	U	0.0075	0.05	U	0.0125	0.054	U	0.0135
1,2,3,4,7,8-HxCDF	0.1	**0.514**		0.0514	**0.055**		0.0055	**0.083**	J	0.0083	**0.021**	**J**	0.0021	0.016	U	0.0008	0.011	U	0.00055
1,2,3,6,7,8-HxCDF	0.1	**0.141**	J	0.0141	0.034	U	0.0017	0.014	U	0.0007	0.012	U	0.0006	0.016	U	0.0008	0.01	U	0.0005
2,3,4,6,7,8-HxCDF	0.1	**0.114**	J	0.0114	0.041	U	0.00205	**0.04**	J	0.004	0.015	U	0.00075	0.018	U	0.0009	0.012	U	0.0006
1,2,3,7,8,9-HxCDF	0.1	**0.107**	U	0.00535	0.06	U	0.003	0.026	U	0.0013	0.023	U	0.00115	0.027	U	0.00135	0.025	U	0.00125
1,2,3,4,6,7,8-HpCDF	0.01	**1.24**		0.0124	**0.246**	J	0.00246	**0.47**	J	0.0047	**0.08**	**J**	0.0008	**0.08**	J	0.0008	**0.081**	J	0.00081
1,2,3,4,7,8,9-HpCDF	0.01	**0.073**	J	0.00073	0.056	U	0.00028	0.036	U	0.00018	0.021	U	0.000105	0.021	U	0.000105	0.015	U	0.000075
OCDF	0.0001	**1.93**		0.000193	**0.403**	J	2.02E-05	**0.942**	J	9.42E-05	**0.136**	**J**	1.36E-05	**0.155**	J	1.55E-05	**0.134**	J	1.34E-05
Total TEQ:				**0.5349**			**0.1417**			**0.1424**			**0.0499**			**0.0641**			**0.0638**
% Lipids (wet weight):				**1.3200**			**0.5940**			**0.2380**			**0.0770**			**0.0840**			**0.0940**

Undetected values quantified at 1/2 detection limit
B = Blank detected in sample
dw = dry weight
J = Estimated Value
JN = Associated value is considered an estimate due to concentration not verified on confirmatory/secondary column
LQ = Lab Qualifier
TEQ = Toxicity Equivalents of 2,3,7,8-TCDD
U = undetected
ww= wet weight

Table 2. Ketron Island Sediment Results for PCDD/F

		AKZ01 - sediment			AKTO1 - Sediment			AKP01 - Sediment			AKP02 - Sediment			AKP03 - Sediment			AKP04 - Sediment			AKB02 - Sediment			AKB03 - Sediment			AKB03 (DUP) - Sediment		
		0-10 cm sample			0-10 cm sample			0-2 cm sample			0-2 cm sample			0-2 cm sample			0-2 cm sample			0-2 cm sample			0-2 cm sample			0-2 cm sample		
Analyte	**TEF**	**ng/kg-dw**	**LQ**	**TEQ**	**ng/kg-dw**	**LQ**	**TEQ**	**ng/kg-dw**	**LQ**	**TEQ**	**ng/kg-dw**	**LQ**	**TEQ**	**ng/kg-dw**	**LQ**	**TEQ**	**ng/kg-dw**	**LQ**	**TEQ**	**ng/kg-dw**	**LQ**	**TEQ**	**ng/kg-dw**	**LQ**	**TEQ**	**ng/kg-dw**	**LQ**	**TEQ**
2,3,7,8-TCDD	1	0.265	U	0.1325	0.356	U	0.178	**0.375**	**J**	0.375	0.211	U	0.1055	**0.286**	J	0.286	0.325	U	0.1625	0.207	U	0.1035	0.154	U	0.077	0.212	U	0.106
1,2,3,7,8-PeCDD	1	**0.61**	J	0.61	**0.592**	J	0.592	**1.42**	**J**	1.42	**0.449**	J	0.449	**0.959**	J	0.959	**0.795**	J	0.795	**0.42**	J	0.42	**0.565**	J	0.565	**0.572**	J	0.572
1,2,3,4,7,8-HxCDD	0.1	0.58	U	0.029	**0.56**	J	0.056	**1.57**	**J**	0.157	0.537	U	0.02685	**0.818**	J	0.0818	0.713	U	0.03565	**0.303**	J	0.0303	**0.527**		0.0527	**0.413**	J	0.0413
1,2,3,6,7,8-HxCDD	0.1	**3.18**		0.318	**3.25**		0.325	**7.22**		0.722	**3.04**		0.304	**4.3**		0.43	**3.8**		0.38	**1.7**	J	0.17	**2.79**		0.279	**2.27**	J	0.227
1,2,3,7,8,9-HxCDD	0.1	**1.74**	J	0.174	**1.69**	J	0.169	**4.11**		0.411	**1.62**	J	0.162	**2.46**	J	0.246	**2.14**	J	0.214	**0.913**	J	0.0913	**1.58**	J	0.158	**1.24**	J	0.124
1,2,3,4,6,7,8-HpCDD	0.01	**46.9**		0.469	**47.4**		0.474	**97.8**		0.978	**44**		0.44	**53.1**		0.531	**52.3**		0.523	**23.4**		0.234	**41.3**		0.413	**28.6**		0.286
OCDD	0.0001	**339**		0.0339	**304**		0.0304	**695**		0.0695	**287**		0.0287	**344**		0.0344	**390**		0.039	**179**		0.0179	**318**		0.0318	**203**		0.0203
2.3.7.8-TCDF	0.1	**1.44**		0.144	**1.67**		0.167	**3.43**		0.343	**1.21**		0.121	**2.65**		0.265	**1.99**		0.199	**0.987**	JN	0.0987	**1.14**		0.114	**1.04**		0.104
1,2,3,7,8-PeCDF	0.05	**0.987**	J	0.04935	**0.887**	J	0.04435	**2.11**	**J**	0.1055	**0.646**	J	0.0323	**1.63**	J	0.0815	**2.52**	J	0.126	0.415	Ug	0.010375	**0.687**	J	0.03435	**0.684**	J	0.0342
2,3,4,7,8-PeCDF	0.5	**1.45**	J	0.725	**1.41**	J	0.705	**3**		1.5	**1.02**	J	0.51	**2.28**	J	1.14	**2.28**	J	1.14	**0.723**	J	0.3615	**1.23**	J	0.615	**0.969**	J	0.4845
1,2,3,4,7,8-HxCDF	0.1	**2.37**	J	0.237	**1.88**	J	0.188	**4.75**		0.475	**1.46**	J	0.146	**3.15**		0.315	**6.61**		0.661	**0.979**	J	0.0979	**1.77**	J	0.177	**1.53**	J	0.153
1,2,3,6,7,8-HxCDF	0.1	**0.901**	J	0.0901	**0.742**	J	0.0742	**1.76**	**J**	0.176	**0.571**	J	0.0571	**1.1**	J	0.11	**2.32**	J	0.232	**0.335**	J	0.0335	**0.684**	J	0.0684	**0.662**	J	0.0662
2,3,4,6,7,8-HxCDF	0.1	**0.959**	J	0.0959	**0.689**	J	0.0689	**1.83**	**J**	0.183	**0.666**	J	0.0666	**1.27**	J	0.127	**1.28**	J	0.128	**0.544**	J	0.0544	**0.755**	J	0.0755	**0.566**	J	0.0566
1,2,3,7,8,9-HxCDF	0.1	**0.517**	J	0.0517	**0.393**	J	0.0393	**0.983**	**J**	0.0983	0.427	U	0.02135	**0.644**	J	0.0644	**0.997**	J	0.0997	0.226	U	0.0113	**0.345**	J	0.0345	**0.26**	J	0.026
1,2,3,4,6,7,8-HpCDF	0.01	**12.8**		0.128	**8.4**		0.084	**24.5**		0.245	**9.52**		0.0952	**13.1**		0.131	**14.3**		0.143	**5.58**		0.0558	**12.1**		0.121	**7.57**		0.0757
1,2,3,4,7,8,9-HpCDF	0.01	**1**	J	0.01	**0.864**	J	0.00864	**1.78**	**J**	0.0178	**0.651**	J	0.00651	**1.05**	J	0.0105	**1.41**	J	0.0141	**0.361**	J	0.00361	**0.773**	J	0.00773	**0.522**	J	0.00522
OCDF	0.0001	**32.8**		0.00328	**22.2**		0.00222	**69.6**		0.00696	**23.2**		0.00232	**37.8**		0.00378	**33.7**		0.00337	**13.3**		0.00133	**29.7**		0.00297	**19.5**		0.00195
Total TEQ:				**3.301**			**3.206**			**7.283**			**2.574**			**4.816**			**4.8953**			**1.795**			**2.8270**			**2.384**
% TOC:				**1.12**			**1.29**			**1.47**			**0.94**		**1.95**				**2.45**			**0.71**			**1.12**			**1.12**

Undetected values quantified at 1/2 detection limit
B = Blank detected in sample
dw = dry weight
J = Estimated Value
LQ = Lab Qualifier
TEQ = Toxicity Equivalents of 2,3,7,8-TCDD
U = undetected
ww= wet weight

3. Conceptual Site Model for PCDD/F Exposure at the Anderson-Ketron Disposal Site

In Section 3, populations that may be affected by PCDD/F in dredged material placed at the A/K site are identified. A Conceptual Site Model (CSM) for exposure associated with PCDD/F-contaminated sediments at and around the Anderson-Ketron disposal site is presented in Figure 4, the components of which are discussed in more detail in the following sections.

3.1 Ecological receptors at the Anderson-Ketron Site

3.1.1 Benthic infauna and epifauna

Dietary uptake from the sediment into the local benthic assemblage of invertebrates, notably clams and polychaete worms, could provide a mechanism for bioaccumulation into foraging crabs and demersal fish. The benthic infaunal community that has been observed at and near the A/K site is summarized in Appendix A, and generally consists of bivalves and polychaete worms. A/K disposal site monitoring data and WDFW monitoring in the vicinity confirm that infaunal organisms, while not present in abundance, are available as suitable food for foraging fish and crabs.

Available information on benthic epifauna (detailed in Appendix B) indicates that there are currently enough Dungeness crabs to sustain a tribal fishery in the A/K area, that Dungeness crab in the South Sound are known to forage at depths equivalent to that at the A/K disposal site, and that potential sources of food are available in the A/K site benthos.

3.1.2 Bottom Fish

Numerous species of demersal fish have been observed in this area and have been collected in the vicinity of the site (see Appendix C). In WDFW surveys, ratfish and English sole comprised the majority (61% and 13%, respectively) of all fish species caught in deep water trawling in south Puget Sound. Given their prevalence and benthic foraging habits, English sole were chosen to represent demersal fish that would receive the greatest exposure to A/K site sediments.

3.1.3 Pelagic fish

Effects from exposure of pelagic fish such as juvenile and adult salmonids to PCDD/F from the A/K site to will not be quantitatively assessed, as it is

presumed that the former have only a limited and transient disposal-site related exposure due to their migratory behavior and pelagic feeding preference, and because neither juvenile nor adult salmonids are likely utilizing the site due to its depth. Thus, based on a qualitative assessment, exposure to salmonids is presumed to be potentially complete but likely insignificant.

3.1.4 Marine Mammals and birds

Exposure to marine mammals (e.g., the killer whale, Orca, and pinnipeds) and birds is also considered complete. However, these pathways are considered qualitatively, with the conclusion that they are not significant. Foraging characteristics (e.g., preferred species, depths, ranges) and partial-year presence in waters near the site are presumed to reduce their exposure to the A/K site area to a very small fraction. For Orca, the dietary contribution of A/K site PCDD/Fs through pelagic fish (predominantly adult resident Chinook salmon), is presumed to be immeasurably small. Chinook do not feed on benthos or at depths .

Figure 4. Conceptual model for PCDD/F exposure at the Anderson-Ketron disposal site

CONCEPTUAL SITE MODEL
ANDERSON-KETRON

PRIMARY SOURCES	RELEASE MECHANISM	PATHWAYS (Exposure Media)	EXPOSURE ROUTE	ECOLOGICAL RECEPTORS				HUMAN RECEPTORS	
				English Sole (benthic)	Dungeness Crab (benthic)	Salmon (pelagic)	Orca (predatory)	Recreationist Fisher	Subsistence Fisher
Site Plus Dredged Material →	Placed in Unit →	Animal Tissue (including bioaccumulation) →	Ingestion	●	●	○	○	○	●

Symbols	
●	Potentially Complete and Significant
○	Potentially Complete but Insignificant

3.2 Human receptors

Human exposure to PCDD/F from dredged material could potentially occur through the consumption of the contaminated crabs or demersal fish. Exposure from consumption of contaminated clams is not substantiated since the A/K disposal site is in deep water and remote from littoral populations of shellfish.

3.2.1 Tribal and recreational exposure

The Anderson-Ketron site falls within the Usual and Accustomed Fishing Area (U&A) of three Tribes (Nisqually, Squaxin and Puyallup), where bottom fishing occurs. Of the three tribes, the Nisqually tribe's fishery resources are most affected by the A/K site. Kris Phelps, the Nisqually shellfish biologist, confirmed that the Nisqually Tribe does have a commercial and subsistence crab fishery whose "exclusive U&A" encompasses the A/K site (Kris Phelps, personal communication). The "In-common U&A" is located approximately 3 miles north of the A/K site and is crabbed by members of the Nisqually, Puyallup and Squaxin Tribes. The Squaxin Tribe appears to have an exclusive U&A in Case Inlet and Dana Passage, approximately 9 miles west of the A/K site.

3.2.2 Recreational fishing exposure

This pathway was not carried forward into the analysis because the protection of Native fishers would also protect recreational fishers due to the greater seafood consumption of the former. Recreational fishers may utilize the site for crab and fish; however, this population would have a considerably lower consumption of fish and shellfish from the site environs than would subsistence Native populations, and typically fish over a greater area than do Native fishers.

4. Calculation of Risk-based Seafood Concentrations for Subsistence Tribal Fishers

In Section 4, regional information on subsistence fisherperson consumption and risk screening calculations are used to calculate a range of risk based tissue concentrations for PCDD/F in bottom fish (represented by English sole) and crabs (represented by Dungeness crab).

The following paragraphs discuss the parameters used in the derivation of the risk-based tissue concentrations for English sole and crab. Tribal subsistence consumers were selected to represent the most highly-exposed population based upon potential high site-related seafood utilization. (Ecological effects are also considered in a later section, and results support this selection.) In Section 5, these risk-based seafood concentrations will be compared to estimated tissue levels in bottom fish and crab arising from assumed exposure to average PCDD/F concentrations in the area of the A/K site.

4.1 Subsistence seafood ingestion rate

4.1.1 Data sources and agency policies considered for selection of ingestion rates

The CERCLA and RCRA programs in EPA Region 10 have been working to develop a "*Draft Framework for Selecting and Using Tribal Fish and Shellfish Consumption Rates for Risk-Based Decision Making at CERCLA and RCRA Cleanup Sites in Puget Sound and the Strait of Georgia*." (EPA Region 10, 2006) Drafts of this document have been shared with the Puget Sound Tribes beginning in December 2004, and EPA's cleanup program's discussions with the Tribes are on-going. EPA's cleanup programs hope to complete a working document later this year. In the meantime, the draft framework has been applied as a pilot for the baseline risk assessment for the Lower Duwamish Waterway National Priorities List site.

The *Draft Framework's* recommendations are based on data from Tulalip (Toy et al., 1996) and the Suquamish Tribe's (Suquamish, 2000) *Consumption Survey*. It presents total consumption rates which are based on the 95th percentile of the distribution of consumption rates of fish and shellfish harvested only from Puget Sound (excluding data from non-consumers) as opposed to the 95th percentile for the entire survey data set. The 95th percentile seafood consumption rate is then subdivided into anadromous, pelagic, bottom fish, and shellfish consumption rates (based on data from consumers and non-consumers).

According to Judi Schwarz, EPA Region 10 policy expert, the *Draft Framework* was prepared to provide guidance to EPA cleanup program staff for developing

possible consumption rates for risk assessments for CERCLA and RCRA sites only and should only be applied in consultation with Tribal governments on a site-specific basis.

No DMMP dredged material disposal sites are designated CERCLA or RCRA sites. However, in the recent past, several disposal sites have received dredged materials that originated from remediation at RCRA and CERCLA sites which was deemed to meet DMMP guidelines. The *Draft Framework* was consulted to assure that a degree of consistency is attained during the risk screening process. Historically, several of the original PSDDA TTLs and BTs presented in EPTA (1988) were derived using human health risk parameters recommended in Superfund guidance. A recent programmatic modification for a site-specific interim TTL for PCBs at the Elliott Bay disposal site (DMMP, 1999), however, used bottom fish specific ingestion rates from subsistence tribal and Asian-Pacific Island populations. The target risk used was 1-in-100,000 (1E-05) ILCR. This is consistent with the tolerable risk levels in the Model Toxics Control Act for mixtures of compounds, and is within the EPA Superfund "risk range" of 1E-06 (1-in-1 million) to 1E-04 (1-in-10,000).

4.1.2 Derivation of an ingestion rate for crab and bottom fish

The *Draft Framework* assumes that the tribal ingestion rate is a constant and that tribal members will use whatever fish/shellfish resources are available to "fill out" the total consumption rate. That is, it recommends for risk assessment that a total ingestion rate be used; but should individual species in isolation be calculated, all such species be considered together to make up the total. In contrast, for this risk screen the DMMP used a species-specific ingestion rate to provide an estimate of exposure, since the principal means of tribal exposure to sediment-related PCDD/F at this location is believed to be via consumption of bottom fish and crabs. Use of the total ingestion rates presented in the draft Framework (194 g/day for Tulalip or 785.1 g/day for Suquamish), was deemed to be too conservative for application in the dredging program.

The focus of this exposure scenario is subsistence fishers from the Nisqually tribe (see Section 3.2.1), as the A/K site falls within the Nisqually's "Usual & Accustomed" area for fishing and in which the Tribe has exclusive use for commercial crabbing. There are, however, no published bottom fish or crab consumption information available for the Nisqually tribe. According to Kris Phelps (Nisqually shellfish biologist), there are 1-6 licensed tribal crabbers placing approximately 50 pots/boat and landing 600-750 lbs per day in the Nisqually reach area during the active crabbing season (K. Phelps, Pers. Comm.). This represents a relatively recently-established crab fishery that has been going on for about 3 years. The tribal crab fishers distribute crabs to other tribal members, as well as selling them to local stores. Maximum crabbing and crab consumption occurs in 2 or 3 months per year, especially in June and July,

although consumption of stored/frozen crab is presumed to occur throughout the year.

Of the available tribal consumption rate information for this region (Tulalip, Suquamish, and Squaxin), it appears that the Tulalip tribe's utilization data most closely resemble the fish/shellfish eating habits of the Nisqually tribe. [9] However, the Nisqually Tribal members may not eat as much crab as the Tulalips so the crab consumption rate of the Tulalip tribal members is a probable overestimate of the ingestion rate of crab by Nisqually Tribal members.

For the purposes of this screening exercise, consumption rates were derived using data from only those tribal members who consume crabs and/or bottom fish rather than relying on ingestion rates that included other species and/or non-consumers. As shown in Appendix D (*Analysis of Tulalip Tribe Puget Sound Crab and Bottom Fish Consumption Rates)***,** consumer-only data from the Tulalip consumption survey was used to derive 95th percentile consumption rates for Puget Sound harvested crab (primarily comprised of Dungeness crab but also including Red rock crab) and bottom fish. An integrated approach was used to address conservatism that might result from summing two separate 95th percentile ingestion rates. The resulting integrated consumption rate is 82.3 g/day crab and 9.5 g/day bottom fish. These consumption rates are based on fish and shellfish consumption of seafood harvested only from Puget Sound. The percent of the total ingestion that is represented by crab was determined using consumption rates from all individuals eating bottom fish and/or crab. Using this approach crab and bottom fish represented 89.7% and 10.3% of the total ingestion, respectively.[10]

4.1.3 Factors affecting tribal ingestion rate

There are several assumptions involving tribal ingestion that confer a degree of conservatism on our screening estimates to support a determination of risk-based seafood concentrations. The most significant of these assumptions include:

- 100% of the Puget Sound-derived bottom fish and crabs come from the vicinity of the A/K site
- All tribal bottom fish and crab consumption is of whole body portions (rather than fillets and edible meat).

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[9] According to Kris Phelps, the Squaxin Tribe only has access to less productive "in-common" crabbing areas to the north and west of the Nisqually Reach and A/K island areas (see Appendix C map), and their actual consumption rates are expected to be lower than the Nisqually Tribe's (K. Phelps, Pers. Comm.).

[10] These percentages were estimated from the Tulalip data representing only those individuals who eat crab and/or bottom fish. If the entire Tulalip data set were evaluated (e.g., individuals consuming anadromous and pelagic species instead of or in addition to crab and bottom fish, the percent intake of crab and bottom fish would be lower.

- Derivation of consumption rates using only bottom fish/crab consumer-only data.
- Use of the 95th percentile of the distribution of crab and bottom fish consumption rates

The DMMP agencies believe that this conservatism is appropriate given that this is a screening exercise and because these assumptions simplify comparison of the risk-based values to the output of modeled seafood concentrations (in Section 5). However, these assumptions and their effect on risk estimates would need quantification (and potentially modification) in the event that risk-based sediment guidelines were developed as part of a programmatic approach to evaluating dioxin in dredged material (see Section 5.2.3 for further discussion of uncertainties).

4.2 Calculation of risk-based seafood concentrations

The overall seafood consumption rate (91.8 g/day) represents the Nisqually tribe's ingestion of English sole and Dungeness crab derived from Puget Sound. We calculated a range of risk-based concentrations assuming three scenarios of bottom fish and crab consumption by a subsistence tribal fisher. In each case, the risk-based concentration was associated with a total target risk of 1E-05 incremental lifetime cancers. The three subsistence ingestion scenarios evaluated were as follows:

1. Consumption of crab only
2. Consumption of bottom fish only
3. Consumption of crab and bottom fish with risk apportioned between the two food items

The tissue concentration of PCDD/F in each food item was back-calculated from a standard risk equation (USEPA, 1989) using the ingestion rate for that food item and the following set of exposure assumptions for subsistence tribal consumers (USEPA Region 10, 2006)**:**

$$C_f = \frac{BW\ (kg) * AT\ (d) * risk}{IR_f\ (kg/meal) * FI\ (fraction) * EF\ (meals/yr) * ED\ (yr) * CSF\ (mg/(kg*d))^{-1}}$$

where:

C_f	concentration PCDD/F in fish and crab (mg/kg TEQ)	
Risk	incremental lifetime cancer risk (total)	1.00E-05
	Apportioned to English Sole	1.03E-06
	Apportioned to Dungeness Crab	8.97E-06
BW	body weight (kg)	81.8
AT	averaging time (days)	25550
IR_f	annualized English sole ingestion rate (kg/day)	0.0095
	annualized crab ingestion rate (kg/day)	0.0823
ED	exposure duration (years)	70
EF	Exposure frequency = 365 meals/yr	365
FI	Fraction of ingestion from site	1
CSF	Carcinogenic slope factor for PCDD/F	1.50E+05

In order to determine the concentration of PCDD/F associated with the target risk (1E-05 incremental lifetime cancers) for a tribal member consuming both English sole and crab, we initially apportioned risk between these two food items. That is, we applied the percentage of total bottom fish and crab intake represented by consumption of English sole (10.3 %) and crab (89.7%) to the total risk. Since we made risk proportional to the ingestion rates, we forced the estimated tissue values to be equal for bottom fish and crab.[11] Because this assumption influences the result, we also considered the effect of a tribal member eating all fish or all crab, in order to provide bounds on the influence of the type of food consumed.

The resulting risk-based concentrations of PCDD/F TEQ in English sole or crab for the three consumption scenarios are:

Scenario	Cf (ng/kg) =	Estimated PCDD/F TEQ		
Apportioned Risk	10.3% diet	English sole	5.91E-02	ng/kg wet
	89.7% diet	Crab	5.94E-02	ng/kg wet
All Risk from Sole	100% diet	English sole	5.74E-01	ng/kg wet
All Risk from Crab	100% diet	Crab	6.63E-02	ng/kg wet

These risk-based concentrations range over an order of magnitude from 0.06 - 0.57 ng/kg PCDD/F TEQ. As noted, they are based on a highly conservative exposure scenario (see discussion in 4.1.3) that would not necessarily be

[11] The only two terms in the risk equation that vary by species are the consumption rate and concentration. Thus you can simplify the standard risk equation to be $C_f = risk/IR_f$. Thus, If risk is proportional to the IR, the calculated concentration in fish/crab will be equal.

applicable to other locations or as the basis for back-calculating a sediment BT. The concentrations were calculated in this fashion in order to provide a point of comparison for estimated tissue concentrations in crab and fish (see Section 5) and to serve as a rough estimate on the feasibility of calculating risk-based sediment guidelines for PCDD/F at this A/K site.

The lower end of this range (associated with apportioned risk or all risk from crab) appears to be problematic with respect to analysis. Recent tissue data (reported in full in Table 1) using EPA Method 1613B is summarized in Table 3. It should be emphasized that during this monitoring event very close coordination occurred with the laboratory, and the values reported are likely to be about as low as possible and are below Practical Quantitation Limits for many labs. In Table 3, one DL (for 2,3,4,7,8-PeCDD) exceeds the low end of the risk-based concentration range, and the highlighted values are flagged as possible contributors to an inability to confidently resolve these tissue concentrations.

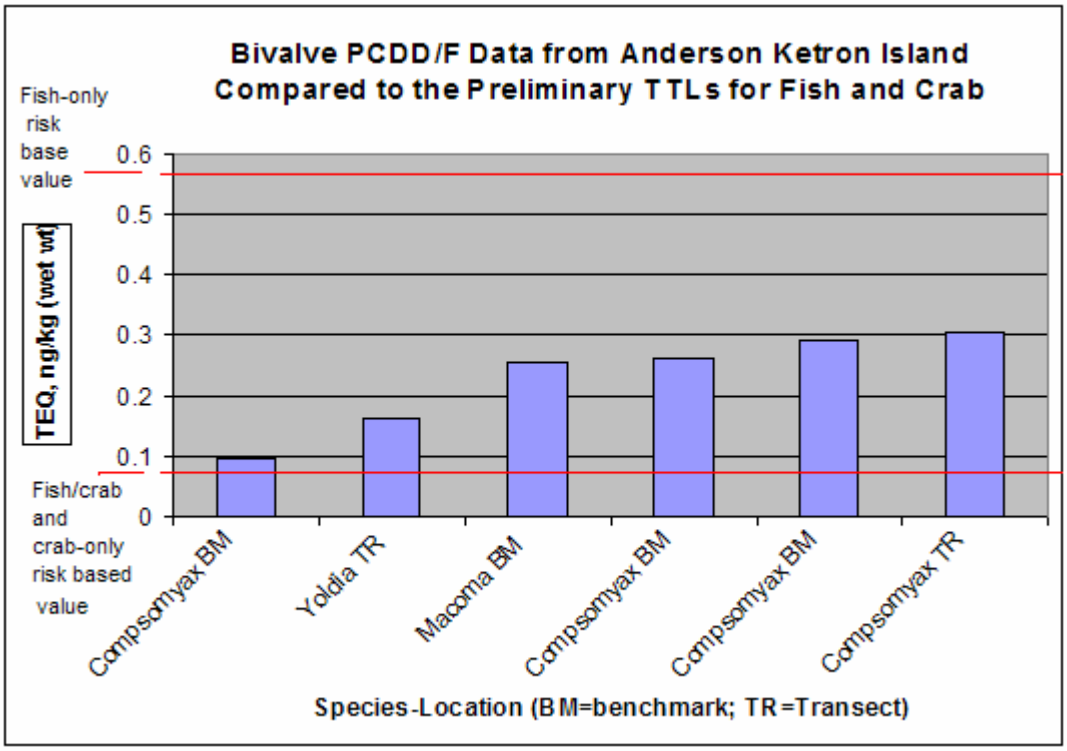
Table 3. Laboratory Detection Limits or Lowest Quantities Detected [12] from Recent Monitoring of 2005 Collected Bivalves at A/K Site.

Analyte	TEF (Dioxins and Furans--- van den Berg (WHO) 1998)	Range of Detection Limits from 2006 A/K work, ng/kg TEQ
2,3,7,8-TCDD	1	0.0085-0.029
1,2,3,7,8-PeCDD	1	0.015-0.0385
1,2,3,4,7,8-HxCDD	0.1	0.0013-0.0166
1,2,3,6,7,8-HxCDD	0.1	0.0046-0.0524
1,2,3,7,8,9-HxCDD	0.1	0.0013-0.0045
1,2,3,4,6,7,8-HpCDD	0.01	INDETERMINATE: <0.00063
OCDD	0.0001	INDETERMINATE: <0.0002
2,3,7,8-TCDF	0.1	INDETERMINATE: <0. 0496
1,2,3,7,8-PeCDF	0.05	0.001425-0.0023
2,3,4,7,8-PeCDF	0.5	0.00135-0.0930.
1,2,3,4,7,8-HxCDF	0.1	00055-0.0055
1,2,3,6,7,8-HxCDF	0.1	0.0007-0.0017
1,2,3,7,8,9-HxCDF	0.1	0.0006-0.002
2,3,4,6,7,8-HxCDF	0.1	0.0015-0.0013
1,2,3,4,6,7,8-HpCDF	0.01	INDET: <0.0008
1,2,3,4,7,8,9-HpCDF	0.01	0.000075-0.00028
OCDF	0.0001	INDETERMINATE: <0,0000942

[12] Range of nondetected values reported in Table 1. If "Indeterminate" is stated, then the lowest J-estimated value or quantitated value reported is shown. The ranges most likely to contribute to quantitation problems at the fish/crab apportioned risk value and crab-only risk value are highlighted.

Figure 5, below, shows the relationship of the A/K bivalve data to the risk-based range of values for bottom fish and crab (represented by two horizontal red lines). Note that this figure is displaying clam data, not fish or crab data. This comparison is apt because PCDD/F and similar compounds typically biomagnify in the food web, so fish and crab could have even higher PCDD/F concentrations. Bioaccumulation is considered further in the next section.

Figure 5. Observed bivalve TEQs from the A/K site in comparison to fish/crab apportioned risk-based values and crab-only risk based values (both lower red line), and fish-only (upper red line).

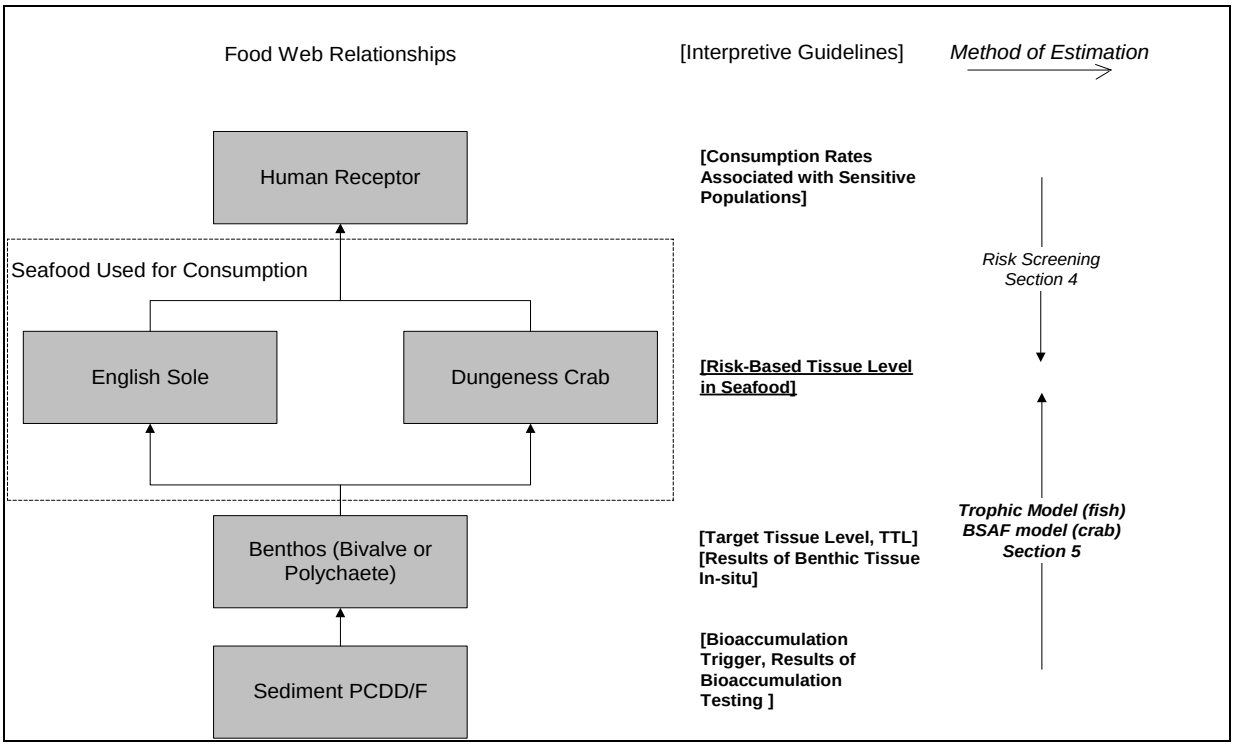


5. Assessment of PCDD/F Bioaccumulation Potential at the A/K Site and Surroundings

In the preceding section, we determined that the risk-based values for bottom fish and crab were in a concentration range that may be difficult to resolve analytically, and we observed that measured PCDD/F TEQ in site clams was above both preliminary crab/fish apportioned and crab-only risk-based values., The DMMP decided to continue with the risk screen and predict the tissue residues of PCDD/F in crab and bottom fish at the site using sediment data from that location.

Figure 6, below, shows a number of interpretive guidelines (e.g., risk-based fish and crab tissue levels that were derived in Section 4). This was a "top-down" approach. The risk-based tissue values can not be used to derive TTLs, because the relationships between the benthic species at this site and the bottom fish and crabs are unknown. Bioaccumulation potential is related to higher trophic levels' lipid content. The lipid content for the bivalves collected at the A/K site ranged from <0.1 - 1.32%, whereas the lipid content of English sole is typically about 5% (Table 4) and Dungeness crab is about 4%. This implies a potential for greater concentrations to be found in seafood species than in site clams. In order to clarify the potential for bioaccumulation, Section 6 describes use of trophic modeling to predict PCDD/F concentrations in bottom fish and crabs, or a "bottom-up" approach.

Figure 6. Diagrammatic representation of food web and methods of estimating interpretive guidelines in this document.



5.1 Modeling English sole and crab tissue residue levels of PCDD/F

The DMMP is not aware of any existing data for PCDD/Fs in tissue of English sole or crab collected either in the vicinity of the A/K site or in South Puget Sound. Thus, the only means to quantify exposure associated with biotic uptake and trophic transfer of sediment-associated PCDD/Fs in the food chain was to model concentrations of PCDD/F in fish and crabs. These modeled concentrations were then compared to the risk based values presented in Section 4 in order to determine the feasibility of establishing risk-based sediment guidelines for PCDD/F at the A/K site.

Sediment concentrations of PCDD/F in the vicinity of the A/K site (1.7 – 7.3 ng/kg TEQ) are at the low end of the range that has been observed in sediment samples collected near urban areas (0.18 – 31.9 ng/kg TEQ). Given these relatively low concentrations as well as the high uncertainty in estimating the fraction of foraging time that a crab or bottom fish would spend at the A/K site (see Appendix B & C), this modeling was limited to a simple prediction of the PCDD/F concentrations in bottom fish and crab that would result from a receptor's lifetime exposure to "background" PCDD/F concentrations in south

Puget Sound. [13] For the modeling, we used Best Professional Judgment to define "background" for this site as the average PCDD/F concentration (3.8 ng/kg TEQ) measured during A/K site and environs testing in the 2005 monitoring event (completed in 2006). This is supported by the lack of trends from onsite to offsite, and the fact that benchmark stations are intended to be unaffected by the site, yet were very comparable to site values. Based on the small amount of PCDD/F information available from non-urban background locations in south Puget Sound (Section 2.3.2), it is possible that this selected background value may be biased high. Therefore, we did not consider using a upper confidence limit on the mean of sediment concentrations as input into the modeling. Also, we did not attempt to account for sole and crab proportion of time at the A/K site, because to the best of our knowledge, there is no difference between onsite and offsite concentrations of PCDD/F.

Two different modeling approaches were used for a screening estimate of PCDD/F in English sole and in Dungeness crab. These were necessitated by the differences between these two species in terms of food gathering behavior as well as kinetics of contaminant uptake and elimination. The food web model used, TrophicTrace (Section 5.1.1), which simulates fish but not crab. A simple partitioning model was used for the crab because relevant BSAF information was available (Section 5.1.2). The following sections describe the two modeling approaches, the assumptions used, and the results of the modeling.

5.1.1 English sole

We used the Corps of Engineers' implementation of the Gobas et al. (1993, 1995) *TrophicTrace* model (available at http://el.erdc.usace.army.mil/arams/) to model PCDD/F TEQ in whole-body English sole. Specifically, *TrophicTrace* estimates the tissue concentration of PCDD/F that would result from an English sole's exposure to sediments averaging 3.8 ng/kg PCDD/F TEQ dry weight (the mean of the 2005 A/K site and environs PCDD/F sediment data). As discussed above, it was assumed that the average PCDD/F concentration in and around the A/K site, 3.8 ng/kg TEQ, was equivalent to that which an English sole would encounter throughout its range. (With more information, it may be possible in future for other sites to accomplish a site-use adjustment.)

TrophicTrace uses a steady-state trophic model to estimate the concentrations of PCDD/Fs in benthic and fish compartments. It may then be used to determine the human health risk associated with exposure to PCDD/F from fish consumption. The exposure inputs to this model that we used are summarized in Table 4. Several specific inputs to *Trophic Trace* such as BSAFs used to estimate the tissue concentration in clams and worms from sediment and the calculated intermediates are presented in detail in Appendix E. It should be

[13] The assumption that there are separate English sole and Dungeness crab populations that remain within south Puget Sound (e.g., south of the Tacoma Narrows) is supported by information provided in Appendices B &C.

noted that the assumed BSAF derived in the Appendix from a variety of marine benthic species, is about 2-3 times higher than the observed clam BSAFs from A/K site monitoring (Section 2 and Figure 3). We retained the higher, literature-derived value because it included other important species, such as polychaetes, that occur on site but were not measured in the monitoring event.

There are benefits and drawbacks to our decision to use *TrophicTrace* to estimate PCDD/F in bottom fish. *TrophicTrace* has been developed to be an accessible and useful tool for screening human health and ecological risk in sediments. Its data requirements are low, and it is easy to use and understand. However, the version of the Gobas model that serves as the basis for *TrophicTrace* has recently been updated to improve the accuracy of predictions (*AquaWeb)* Arnot and Gobas, 2005). This version was not as usable in this screening exercise, as we did not have a risk-assessment interface to accomplish the screening, in particular to relate a risk-based tissue value to a sediment value.

TrophicTrace may overestimate concentrations of high Kow chemicals (such as PCDD/Fs) because it does not permit the user to input differential metabolic elimination of PCDD/F, although this may be an influential factor in assessing PCDD/F uptake (Lawrence Burkhard, EPA, pers. comm.). If future efforts to develop programmatic guidance involve modeling PCDD/Fs in higher trophic level receptors, the DMMP will consider whether to use the *AquaWeb* model and use site-related data to calibrate it to better account for the complexity of PCDD/F bioaccumulation. It is hoped that in future we may interface *AquaWeb* with a risk estimation program (e.g., *ARAMS/FRAMES*: Zakikhani, et al. 2006) to give it the functionality of TrophicTrace for screening purposes.

5.1.2 Dungeness Crab

PCDD/F concentrations in crab were estimated using congener-specific biota-sediment accumulation factors (BSAFs) from a study on Dungeness crab in British Columbia (Yunker and Cretney, 2000). The authors calculated congener-specific BSAFs using a historical data set comprised of a large number of synoptic samplings of crab hepatopancreas and sediment. [14] The Yunker and Cretney data were log-normally distributed and neither an arithmetic mean nor median is the best estimator of central tendency. Typically, the best estimate will be somewhere above the median and below the mean. In order to bracket the best estimate, we estimated crab concentrations using both mean and median BSAFs. The mean and median BSAF values reported and the estimates are provided below in Table 5a and 5b. Using both mean and median conger-specific BSAFs and the mean sediment concentrations of individual PCDD/F congeners from the A/K site and environs, we estimated a range of PCDD/F

[14] The crab hepatopancreas is high in lipids and is consumed by some subsistence populations. As a result, monitoring of lipophilic contaminants in crabs often focuses on analysis of the hepatopancreas.

TEQ in crab hepatopancreas (Tables 5a and 5b). These estimated values, however, are for hepatopancreas only. In order to compare these modeled data with risk-based values derived for crab in Section 4, it was necessary to convert them to units of whole-crab-body TEQ. The only known Puget Sound data set reporting PCDD/F in both hepatopancreas and edible muscle tissue of Puget Sound Dungeness crab is in PTI (1991), and this summarized in Table 6.[15] Based on the PTI data set, the DMMP determined that the ratio of PCDD/F TEQ in whole body as compared to crab hepatopancreas is 1.12. This ratio was used to convert the estimated TEQs in hepatopancreas to estimated values for the whole body crab.

[15] Note that none of these samples were taken from south Puget Sound.

Table 4. Parameters used in Trophic Trace Modeling of English sole exposed to PCDD/F in vicinity of A/K Site.

	Value	Units	Source/Comment
1. Chemical Properties			
a. Dioxin, 2,3,78-TCDD equivalents	CAS 1746-01-6		RAIS
b. Log10 Kow	6.3	(none)	*Congener*-weighted average Log Kow based on congener distributions in 2005 Anderson-Ketron site data (Appendix D)
c. Log10 Koc for 2,3,7,8-TCDD	5.9	(none)	*Congener*-weighted average Log Koc based on congener distributions in 2005 Anderson-Ketron site data. (Appendix D)
d. Cancer Slope Factor	1.50E+05	(none)	HEAST
e. Biota-Sediment Accumulation Factor	0.614	(none)	BSAFs from Clarke & McFarland (2004) weighted using the congener distributions from 2005 Anderson-Ketron site data. (Appendix E).
2. Anderson-Ketron Island Site Characteristics			
a. Surface Water Temperature	12.8	deg C	Average Surface Water Temperature in Puget Sound
b. Percent TOC	1.38	%	Mean from 2005 Anderson-Ketron site data
c. Particulate OC	0.06	mg/L	Parsons, 1984
d. Dissolved OC	1.2	mg/L	Parsons, 1984
e. Sediment PCDD/F	3.8	ng/kg TEQ	Mean from 2005 Anderson-Ketron site data
3. Invertebrate Community (Level 1)			
a. Bivalve Tissue Lipid	0.401	%, wet wt.	Mean from bivalves (*Macoma, Yoldia, Compsomyax)* collected around the A/K site during 2005 monitoring.
b. Polychaete Tissue Lipid	1.3	%, wet wt.	Mean lipid value in *Nephtys caecoides* collected from Tomales Bay, CA. No A/K site data available.
4. Fish,and Ecorisk			
a. English Sole (*Pleuronectes vetulus*)			
a1. Feeding Habit	Forage (Level 2)	(none)	Knowledge of habit
a2. Tissue Lipid	5.16	%, wet wt.	Whole body data from LDWG 2004 and 2005; value is the mean of the distribution. No A/K site data available.
a3. Mean Body Weight	199.1	g	Whole body data from LDWG (2004 and 2005); values is mean of the distribution. No A/K site data available.
a4. % of Sole Range represented by A/K site and environs	100	%	Assumed that average concentration from A/K monitoring (3.8 ng/kg dw) is representative PCDD/F concentration for all sediments encountered by S. Sound population of Sole.
a5. bivalves and polychaetes as Percent of diet	50% each	%	Assumption based on literature indicating that they are both important in E. sole diet
a6. LOAEL based critical body residue	1.7E-05	mg/kg, wet wt.	See Table 7 for derivation.

Table 5a. Values used to estimate PCDD/F in A/K Dungeness Crab (using mean BSAFs)

	Mean hepat. BSAF [a]	Mean congener-specific TEQ from A/K seds [b] ng/kg-TOC	Estimated TEQs in crab hepat. [c] ng/kg Hepat. Lipid	Assumed hepat. lipid [d] %	TEQs in hepat. ng/kg	Hepat. = 31% of a 350g crab kg	Hepat. TEQs ng/crab	Total TEQ/ Hepat TEQ[e]	Total TEQ ng/crab	Total TEQ in 350 g crab, ng/kg
2,3,7,8-TCDD	2.400	13.298	31.916	9.8%	3.128	0.109	0.339	1.122	0.381	1.088107
1,2,3,7,8-PeCDD	1.700	54.527	92.696	9.8%	9.084	0.109	0.986	1.122	1.106	3.160313
1,2,3,4,7,8-HxCDD	0.000	4.322	0.000	9.8%	0.000	0.109	0.000	1.122	0.000	0.000000
1,2,3,6,7,8-HxCDD	0.710	27.393	19.449	9.8%	1.906	0.109	0.207	1.122	0.232	0.663091
1,2,3,7,8,9-HxCDD	0.320	15.080	4.825	9.8%	0.473	0.109	0.051	1.122	0.058	0.164516
1,2,3,4,6,7,8-HpCDD	0.100	38.090	3.809	9.8%	0.373	0.109	0.041	1.122	0.045	0.129862
OCDD	0.070	2.671	0.187	9.8%	0.018	0.109	0.002	1.122	0.002	0.006375
2.3.7.8-TCDF	4.000	13.418	53.670	9.8%	5.260	0.109	0.571	1.122	0.640	1.829799
1,2,3,7,8-PeCDF	1.600	4.041	6.465	9.8%	0.634	0.109	0.069	1.122	0.077	0.220410
2,3,4,7,8-PeCDF	1.600	60.090	96.144	9.8%	9.422	0.109	1.022	1.122	1.147	3.277881
1,2,3,4,7,8-HxCDF	0.880	19.417	17.087	9.8%	1.675	0.109	0.182	1.122	0.204	0.582548
1,2,3,6,7,8-HxCDF	0.490	7.215	3.535	9.8%	0.346	0.109	0.038	1.122	0.042	0.120530
2,3,4,6,7,8-HxCDF	0.380	7.342	2.790	9.8%	0.273	0.109	0.030	1.122	0.033	0.095115
1,2,3,7,8,9-HxCDF	0.000	3.538	0.000	9.8%	0.000	0.109	0.000	1.122	0.000	0.000000
1,2,3,4,6,7,8-HpCDF	0.190	9.242	1.756	9.8%	0.172	0.109	0.019	1.122	0.021	0.059870
1,2,3,4,7,8,9-HpCDF	0.000	0.709	0.000	9.8%	0.000	0.109	0.000	1.122	0.000	0.000000
OCDF	0.030	0.240	0.007	9.8%	0.001	0.109	0.000	1.122	0.000	0.000246
Sum		280.633	334.337						3.990	11.399

Hepat = hepatopancreas or green gland

a – From Yunker and Cretney (2000)

b – From 2005 DMMP A/K site and environs monitoring.

c – Using $BSAF_{hepat} = \frac{C_{hepat}/f_{hepat\text{-}lipid}}{C_{sed}/f_{OC}}$

d – From PTI (1991) data based on data presented in Table 6.

e – From PTI (1991) ratio of TEQ in whole body to hepatopancreas.

Table 5b. Values used to estimate PCDD/F in A/K Dungeness Crab (using median BSAFs)

	Median hepat. BSAF [a]	Mean congener-specific TEQ from A/K seds [b] ng/kg-TOC	Estimated TEQs in crab hepat. [c] ng/kg Hepat. Lipid	Assumed hepat. lipid [d] %	TEQs in hepat. ng/kg	Hepat. = 31% of a 350g crab kg	Hepat. TEQs ng/crab	Total TEQ/ Hepat TEQ[e]	Total TEQ ng/crab	Total TEQ in 350 g crab, ng/kg
2,3,7,8-TCDD	1.400	13.298	18.617	9.8%	1.825	0.109	0.198	1.122	0.222	0.634729
1,2,3,7,8-PeCDD	0.850	54.527	46.348	9.8%	4.542	0.109	0.493	1.122	0.553	1.580156
1,2,3,4,7,8-HxCDD	0.000	4.322	0.000	9.8%	0.000	0.109	0.000	1.122	0.000	0.000000
1,2,3,6,7,8-HxCDD	0.330	27.393	9.040	9.8%	0.886	0.109	0.096	1.122	0.108	0.308197
1,2,3,7,8,9-HxCDD	0.140	15.080	2.111	9.8%	0.207	0.109	0.022	1.122	0.025	0.071976
1,2,3,4,6,7,8-HpCDD	0.050	38.090	1.905	9.8%	0.187	0.109	0.020	1.122	0.023	0.064931
OCDD	0.010	2.671	0.027	9.8%	0.003	0.109	0.000	1.122	0.000	0.000911
2.3.7.8-TCDF	1.900	13.418	25.493	9.8%	2.498	0.109	0.271	1.122	0.304	0.869155
1,2,3,7,8-PeCDF	0.670	4.041	2.707	9.8%	0.265	0.109	0.029	1.122	0.032	0.092297
2,3,4,7,8-PeCDF	0.900	60.090	54.081	9.8%	5.300	0.109	0.575	1.122	0.645	1.843808
1,2,3,4,7,8-HxCDF	0.240	19.417	4.660	9.8%	0.457	0.109	0.050	1.122	0.056	0.158877
1,2,3,6,7,8-HxCDF	0.160	7.215	1.154	9.8%	0.113	0.109	0.012	1.122	0.014	0.039357
2,3,4,6,7,8-HxCDF	0.170	7.342	1.248	9.8%	0.122	0.109	0.013	1.122	0.015	0.042551
1,2,3,7,8,9-HxCDF	0.000	3.538	0.000	9.8%	0.000	0.109	0.000	1.122	0.000	0.000000
1,2,3,4,6,7,8-HpCDF	0.070	9.242	0.647	9.8%	0.063	0.109	0.007	1.122	0.008	0.022057
1,2,3,4,7,8,9-HpCDF	0.000	0.709	0.000	9.8%	0.000	0.109	0.000	1.122	0.000	0.000000
OCDF	0.009	0.240	0.002	9.8%	0.000	0.109	0.000	1.122	0.000	0.000074
Sum		280.633	168.041						2.005	5.729

Hepat = hepatopancreas or green gland

a – From Yunker and Cretney (2000)

b – From 2005 DMMP A/K site and environs monitoring.

c – Using $BSAF_{hepat} = \frac{C_{hepat}/f_{hepat\text{-}lipid}}{C_{sed}/f_{OC}}$

d – From PTI (1991) data based on data presented in Table 6.

e – From PTI (1991) ratio of TEQ in whole body to hepatopancreas.

Table 6. PCDD/F in Crab hepatopancreas and muscle from areas in Puget Sound (from PTI, 1991) [a]

	Hepatopancreas		Muscle		Calculated Whole Crab [b]
Dungeness Crabs	ng/kg wet wt	% Lipid	ng/kg wet wt	% Lipid	ng/kg wet wt
Bellingham Bay	14.6	11.00%	0.3	3.62%	4.7
Dungeness Bay	1.6	9.00%	0.3	2.98%	0.7
Elliott Bay	21.3	8.20%	0.5	2.75%	7.0
Everett Harbor	66.7	9.70%	0.4	3.11%	20.9
March Point	17.8	11.00%	0.4	3.58%	5.8
West Point 1 (males only)	15.1	9.80%	0.4	3.26%	4.9
Average of Above	22.8	9.78%	0.4	3.22%	7.3
***Average without Everett* (which was an outlier)**	**14.1**	**9.80%**	**0.4**	**3.24%**	**4.6**

[a] Recalculated from the original report using the I-TEF (Van de Berg, 1998)
[b] Assuming a 450g crab (100 g shell and 350 g total edible meat) and that the hepatopancreas is 31% of edible meat by weight.

5.1.3 Modeling Results

The modeling results for English sole and Dungeness crab (as well as their prey items) are summarized in Table 7. Estimated TEQ concentrations in English sole tissue (assuming lifetime exposure to sediments with an average PCDD/F of 3.8 ng/kg TEQ dry weight) were slightly lower than that estimated in Dungeness crab. There is no known PCDD/F tissue data for either species from south Puget Sound to which we can compare these values. However, the range of estimated TEQ in whole Dungeness crab (5.7 - 11.4 ng/Kg TEQ wet weight) falls between measured values from urban (Everett Harbor and Elliott Bay) and presumed non-urban areas of Puget Sound, summarized in Table 6. The fact that PCDD/F TEQs in our modeled fish and crabs are within the range of what has been measured in Puget Sound tends to confirm the reasonability of the values provided by the modeling for this risk screening exercise, but not the accuracy of the prediction; that will require calibration of the model, as stated. Therefore, future monitoring at the A/K site should include analysis of English sole and Dungeness crab as a check on the accuracy of this modeling for predicting PCDD/F concentrations in these two receptors.

Table 7. Modeled and Measured concentrations of PCDD/F in sediments and biota associated with the A/K Site

	Modeling approach	Estimated PCDD/F TEQ ng/kg wet wt	Measured PCDD/F TEQ [a] ng/kg
Sediment	(None—measured)		mean = 3.8 (dry wt; n= 8)
Polychaete	BSAF – *TrophicTrace*	2.2	na
Bivalve	BSAF – *TrophicTrace*	0.68	mean = 0.17 (wet wt; n=5)
English sole	*TrophicTrace*	4.37	na
Dungeness Crab	Yunker & Cretney BSAF (tables 5a and 5b) [b]	5.7/11.4	na

na – not available
[a] – From 2005 A/K site monitoring
[b] – values based on using median BSAFs/mean BSAFs reported in Yunker & Cretney (2000).

5.2 Effects assessment

5.2.1 Human Health

A range of tissue concentrations were derived in Section 4.2, assuming subsistence tribal consumption of crab-only, bottom-fish only and risk-proportionate consumption of both species. In each case, these tissue values are equal to an estimated incremental lifetime cancer risk of 1 in 100,000. The modeled concentration of PCDD/F in English sole (4.37 ng/Kg TEQ wet weight) is one to two orders of magnitude higher than the range of risk-based concentrations for bottom fish (0.059 - 0.57 ng/kg TEQ wet weight). Modeled concentrations of PCDD/F TEQ in Dungeness crab (5.7 - 11.4 ng/Kg TEQ wet weight) are more than two orders of magnitude higher than the range of risk-based concentrations (0.059- 0.066 ng/kg TEQ wet weight). Thus, the predicted risks based on a conservative estimate of subsistence level consumption of crabs and/or bottom fish (having a lifetime exposure to sediment PCDD/Fs at the low end of urban background) are considerably above the risk target value of 1E-05 ILCR.

5.2.2 Ecological

The ecological effects to English sole of PCDD/F exposure were evaluated quantitatively following EPA Ecological Risk Guidance (1997) using as a benchmark a value between the Lowest-effects Residue (LOER) and No-effects Residue (NOER) for whole body, derived from data on brook-trout eggs and reported in Steevens et al. (2005) Steevens and his colleagues developed a methodology for deriving a tissue residue benchmark for fish for 2,3,7,8-TCDD, using the geometric mean of the no-observed effect residue (NOER) and lowest observed effect residue (LOER). The fish species included several trout

species, the northern pike, the white sucker, and the zebra fish, but no marine species. The benchmark values derived are summarized in Table 8. A range of population protection values (deemed “species protection values” in the paper) were described, so that the risk managers may decide which level of protection is desirable.

Table 8. Tissue Residue Benchmark Values from Stevens et al. (2005)

Species Protection Level	Benchmark Value (ng TEQ/kg lipid)	Benchmark Value (ng TEQ/kg), at lipid fraction = 0.0516
99%	57	3
97.5%	151	8*
95%	321	17
90%	699	36

*This value is closest to the predicted value in terms of protection.

For this risk screen, the DMMP selected a 95% protection value (17 ng/kg wet weight TEQ), which is the same protection level used by EPA in publishing National Ambient Water Quality Criteria. The estimated concentrations of PCDD/F TEQ in English sole (4.37 ng/Kg wet weight) results in protection of more than 97.5% of the population, and no adverse effects in English sole are expected at the estimated tissue concentrations associated with exposure to the A/K site and environs.

There were no environmental residue-effects values available for Dungeness crab and therefore the effects of PCDD/F on crab were not quantitatively evaluated.

5.2.3 Uncertainty assessment

This document represents a screening approach to determine the feasibility of establishment of a TTL and BT. The risk screen estimates are likely to be over-estimates of actual risks determined by a full risk assessment. The following is presented to illustrate the need to define further risk screening or assessment procedures. The majority of the factors below could qualitatively lead to an overestimate of risk. However, for this screening approach, there was not time to accomplish a quantitative uncertainty assessment (e.g., Monte Carlo probabilistic methods).

Table 9. Summary of Uncertainties in Exposure Assessment

Source of Uncertainty	Potential Impact on Exposure Estimate
Concentration in Sediment • Assumed concentration at site is representative of South Puget Sound non-urban background	• Overestimate if true "background" is less than site
Concentration in Benthos • Bivalves are the only benthos for which data exist at A/K site, but other species are consumed by fish and crab • Analytical limitations for quantitating PCDD/F at low levels near risk-based concentrations	• Unknown[16] • Unknown[17]
Fish/Crab Consumption Estimates for Tribal Fishers • Use of 95% upper confidence limit on distribution • Use of data set for another tribe from North Puget Sound • Use of consumer-only tribal data and assumption of site-and-surroundings derived catch • Lack of consideration of other sources of fish (e.g., supermarket) • Use of only certain species or guilds for exposure assessment • Assumption of crab-to-fish proportion • Assumption that whole crab is eaten	• Overestimate • Unknown or overestimate of crab consumption • Overestimate • Overestimate • Unknown, or underestimate (in terms of *Draft Framework*) • Minor effect if affected population predominantly eats crab; overestimate if fish are eaten instead of crab • Overestimate (76% of Tulalips eat only muscle)
Modeling of Sediment to Biota • Use of TrophicTrace Model that does not permit elimination of PCDD/F • Availability of more recent model that has been more extensively calibrated with bioaccumulating chemicals (PCB) • Congener weighting of BSAF from literature; Observed BSAF is 2-3 times lower than BSAF selected for modeling • Congener weighting of Kow and Koc	• Overestimate • Unknown or overestimate • Overestimate • Unknown

[16] Polychaete worms typically have a higher percentage lipid than do bivalves.
[17] The consequence of this unknown may be the assumption that tissue is contaminated when it is not; it may therefore be an overestimate from a risk management perspective.

6. Conclusions and Recommendations

6.1 BT and TTL for Anderson-Ketron

Based on the screening risk exercise and modeling presented in Sections 4 & 5, the DMMP agencies have concluded that it is not possible through risk assessment to establish TTLs or BTs for the A/K site at this time for the following reasons:

- Predicted concentrations of PCDD/F TEQ in English sole and Dungeness crab tissue (assuming lifetime exposure to sediment dioxin concentrations at the low end of urban background - the A/K site and environs mean PCDD/F of 3.8 ng/Kg TEQ dry weight) are significantly higher than risk-based maximum concentrations, although the evaluation is based on both a possible over-prediction of body burdens of PCDD/F in fish and crab as well as a conservatively high estimate of tribal subsistence consumption of these two species.

- While the A/K site itself may not comprise a substantial part of the foraging area of either English sole or Dungeness crab, there are insufficient biological data available to quantify the effect of increasing the PCDD/F concentrations at the site on these receptors.

- Sediment PCDD/F TEQs measured in and around the A/K site during 2005 monitoring are at concentrations which the DMMP considers to represent the low end of urban background and, potentially, the high end of non-urban background.

- It would not be practicable or advisable to establish interpretive criteria (BT or TTL) which very near or possibly below background or analytical limits of detection.

A full evaluation of the practicability of establishing risk-based guidance for PCDD/Fs at open water disposal sites will require a more intensive modeling effort and risk analysis that was conducted in this screening exercise. However, in order to proceed with the Port of Olympia suitability determination in a timely manner, we decided that an interim approach was needed to determine acceptable concentrations of PCDD/Fs in sediment to be disposed at the A/K site.

6.2 Options for developing numerical limits for PCDD/F at Anderson-Ketron

There are several reasonable approaches to developing numerical limits for allowable concentrations of PCDD/F in sediments for the A/K disposal site. These include:

1. Risk-based sediment criteria
2. "Background-based" criteria
3. Prohibition on disposal of sediments with detectable PCDD/Fs

As discussed earlier, the results of this screening exercise indicate that a risk-based approach to setting numerical guidelines to protect tribal subsistence consumers would likely result in a sediment threshold that approached or was below analytical limits of detection. Likewise, prohibiting disposal of all sediments with detectable PCDD/Fs is an unacceptable approach given that current PCDD/F sediment concentrations in and around the A/K site are already above detection. Furthermore, such an approach would not be consistent with Site Condition II ("minor adverse impacts") that was selected by PSDDA (EPTA, 1988) to be the management condition for unconfined, open water disposal. [18]

A "background-based" approach involves setting numerical limits for PCDD/Fs in dredged material such that disposal will not result in sediment concentrations of PCDD/F at the site in excess of what is considered to be "background". The term "background", however, requires definition in this case. While "urban background" has been characterized in several Puget Sound locations for the purposes of remedial decision-making (see Section 2.3.2), there is no generally accepted definition for urban- or non-urban "background" nor agreement on what type of background would be applicable to open-water disposal sites, particularly one such as the A/K site which is located in a relatively pristine, non-urban location with a nearby active commercial crab fishery.

Given the lack of an agreed-upon basis for setting urban- or non-urban background, the DMMP decided to base interim guidelines for the A/K site on the site-specific data that was collected from this area in 2005 (Table 2). As discussed in Section 2, these data are believed to represent non-impacted conditions at the A/K site based on the lack of known sources of dioxin both in the vicinity of the site and in the sediments that have been previously disposed at the site. A programmatic decision on whether and what form of "background" is applicable at this and other disposal site will be decided based on broader input from stakeholders at upcoming meetings on this topic.

[18] Note that the acceptable minor adverse effects described in EPTA were described as follows: "Effects represented by Site Condition II….are expected to consist of some chronic effects on-site but no significant effects offsite...(these) will include sublethal effects and, potentially an increase in the mortality of the more sensitive but less abundant crustacean species…Measurable tissue contaminant levels may result at Site Condition II, but these levels are not expected to present a human health problem." (EPTA, 1988)

6.3 A recommended interim "background-based" approach for PCDD/F at the Anderson-Ketron site

We have developed the following interim approach to determining the suitability of dredged material from the Port of Olympia containing PCDD/F at the Anderson-Ketron site (summarized in Figures 4 and 5). The goal of this approach is to set numerical limits for PCDD/Fs in dredged material such that disposal will not result in a significant increase in sediment concentrations of PCDD/F at the site.

The pre-testing process (Figure 6a) involves determining the need for requiring PCDD/F analysis on project sediments, developing and executing a sampling and analysis plan (SAP), and establishing disposal site background conditions for PCDD/F. The reason-to-believe approach has long been used by the DMMP to determine the need for PCDD/F testing. Likewise, the DMMP has a standard process and templates for developing SAPs for chemicals of concern which are described in the User's Manual (PSDDA 2000). The sediment PCDD/F data from the A/K site and environs is summarized in Table 9.

Table 9. Summary statistics for Anderson-Ketron sediment PCDD/F samples (2005)

Number of Unique Samples	8
Minimum	1.80
Maximum	7.28
Mean	3.81
Median	3.25
Standard Deviation	1.77
Variance	3.13
Coefficient of Variation	0.46
Skewness	1.10

All concentration data are in ng/kg dry weight

The two highlighted rows in Table 8 are the maximum and mean TEQ value based on the eight samples analyzed. [19] These two values are used in the suitability determination process (Figure 5) as pass/fail criteria.

The suitability determination process (Figure 5b) involves a two step comparison to the A/K site maximum and mean values. First, the data from each DMMU is compared to the A/K site maximum (7.3 ng/kg dry weight). Any DMMU with PCDD/F TEQ concentrations in excess of this value is unsuitable for disposal at

[19] The depth intervals in these samples were not consistent; 6 of the 8 samples tested represented recently deposited material (0-2 cm) while the other two samples represented the 0-10 cm depth interval.

the A/K site and should be removed from the pool of DMMUs being considered for open water disposal at this site. Second, the volume-weighted PCDD/F TEQ in each of the remaining DMMUs are combined to form a volume weighted mean TEQ for the remaining project sediments. This value is compared to the site mean (3.8 ng/kg dry weight) to determine the suitability of the remaining DMMUs for disposal. If the volume-weighted mean project TEQ is greater than the site mean, it is possible to remove individual DMMUs until the volume-weighted project mean is less than 3.8 ng/kg dry weight.

This interim approach is a departure from the usual process used by the DMMP for other COCs. Notably, the DMMP usually determines suitability individually for each DMMU whereas this background approach includes consideration of a volume-weighted mean TEQ. As an interim measure, we believe that this is appropriate, since it includes provisions to both remove individual DMMUs with elevated PCDD/F concentrations, as well as assuring that the total PCDD/F TEQ from the remaining project sediments does not exceed the current mean site concentration. As the DMMP's intent is not to significantly increase the average surface concentrations of PCDD/F at the A/K site, sequencing (placing cleanest dredged material last) may also aid in maintaining the site condition.

Figure 7a. Determination of Reason-to-Believe and Sampling Process

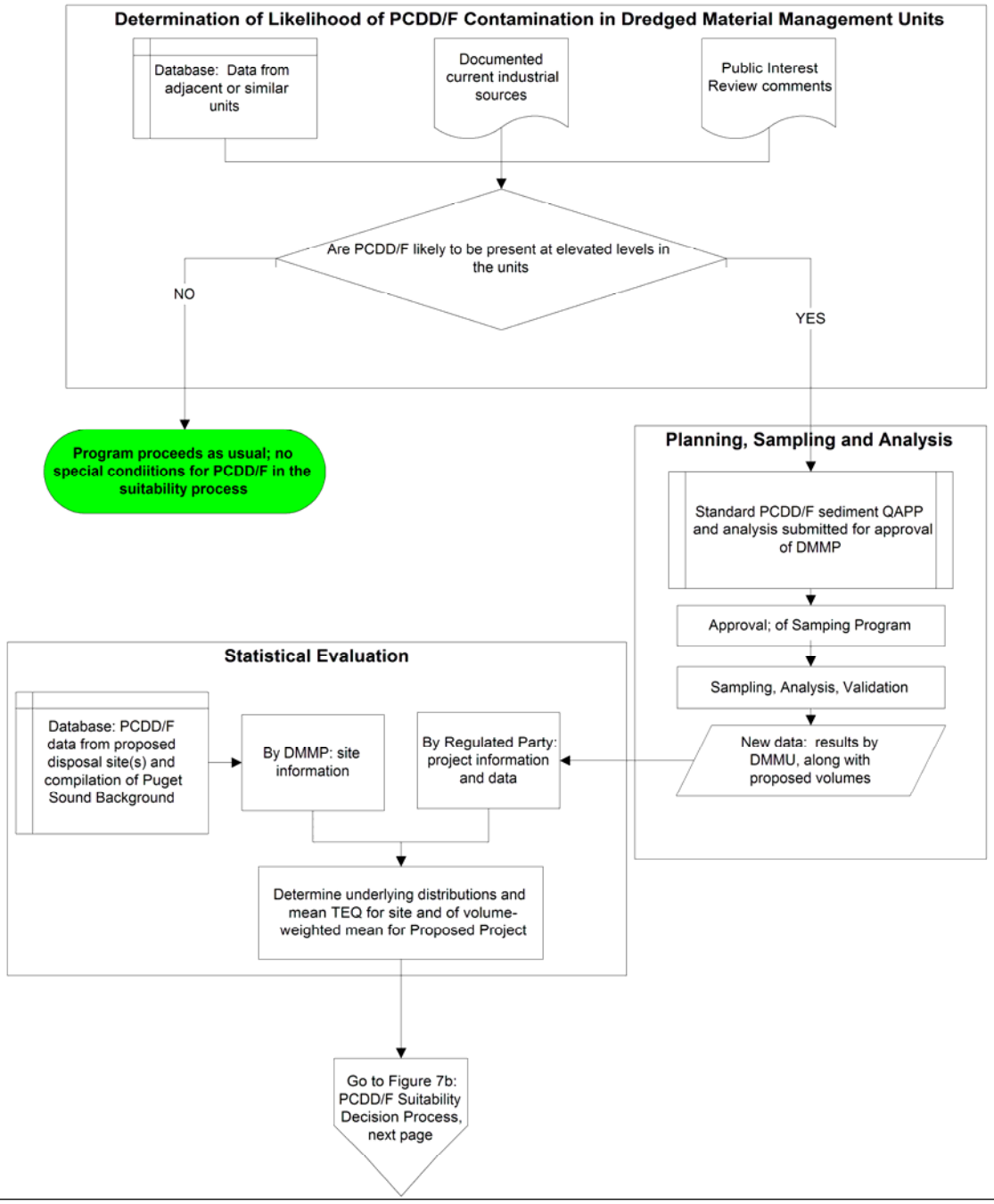
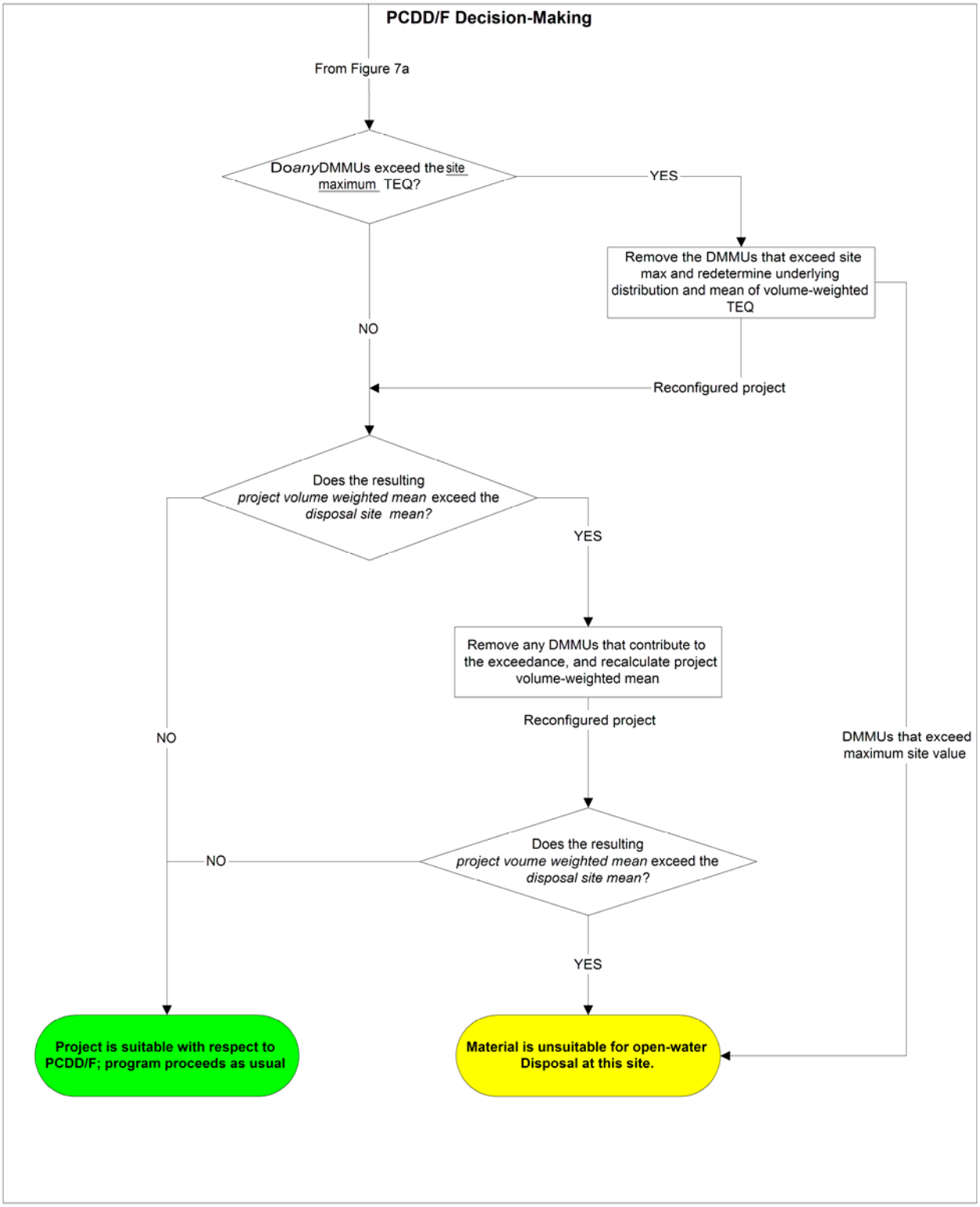


Figure 7b. PSDDA Suitability Determinations for PCDD/F



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Appendices

Appendix A. Information on the Benthic Community at the Anderson-Ketron Site.

The following benthic invertebrate information was compiled and reviewed, with the intent of determining the population characteristics of interest (species, weight, lipid content) for modeling PCDD/F in English sole:

- Wayne Palsson (WDFW) provided GIS density plots presenting compiled WDFW trawl data for invertebrates from 1996-2005 (Figure A-1). Data was collected from an area extending from the Tacoma Narrows to approximately 8 miles south. Total invertebrate densities at deep stations ranged from <3 kg/ha to 517 kg/ha. Invertebrate densities in the vicinity of the A/K site were generally the lowest measured in the area reviewed.
- DMMP's A/K site monitoring data report from 2005 (SAIC). Dominant benthic taxa (in terms of abundance and biomass) at the transect stations moving away from the site are bivalves (e.g., *Axinopsida sp*.) and polychaetes (e.g., *Levinsenia sp*). *Axinopsida* are very small, opportunistic bivalves and have been found in the stomachs of bottom fish (baseline surveys). *Macoma* (bivalve) were also among the subdominant taxa observed at the transect stations. *Nephtys* sp. (polychaetes) have been identified at the transect stations but in small numbers.
- A limited analysis of *in-situ* benthic tissues from transect and benchmark stations was performed as part of the DMMP's 2005 A/K monitoring effort. Given the sample biomass (60 g/ sample) required by the commercial lab to analyze for the DMMP's COC list, larger organisms were targeted for tissue analysis. Generally, these larger organisms were not among the dominant or subdominant spp. according to the benthic community analysis of transect stations. In the 2005 monitoring, all organisms collected for tissue analysis were bivalves (*Compsomyax*, *Macoma sp.* and *Yoldia*). Collection of these organisms involved multiple drops of the sampler and was completed separately from sediment collected for benthic taxa/biomass analysis. All tissues (including those from other stations) were archived. PCDD/F and lipid results for these archived samples are presented in Table 1 (Section 2.2 in the main text).
- We searched for additional lipid data for field-collected benthic organisms which could be found at the depths (>400 ft) of the A/K site. One source of data identified was that provided as part of the standardized bioaccumulation testing which uses the polychaete, *Nephtys caecoides* and the bivalve, *Macoma nasuta. Macoma* has been identified as a subdominant species at the transect sites. *Nephtys* has been seen at the transect sites but is not among the dominant or subdominant polychaetes species.

  Sources of lipid data were dredging-related and DMMP site monitoring studies performed between 1989-2005. Lipid data from pre-test or "background"

samples were used to eliminate any potential effects that the 28-45-day test times may have on lipid metabolism during laboratory bioaccumulation tests. *Macoma* and *Nephtys* used were collected from Discovery Bay, WA and Tomales Bay, CA, respectively and were held less than 3 weeks in the laboratory in control sediments without supplemental feeding. Background samples for a given species were generally comprised of tissue from 30-45 individuals which were composited and analyzed in triplicate (ranging from 1-5 samples). Multiple analyses from one composite were averaged. Mean lipid value for *Nephtys* collected from Tomales Bay (CA) was 1.3% wet (n=7). Mean lipid values for *Macoma* collected from Discovery Bay was 1.09% (n=6).

- Another source of lipid data was from an unpublished EPA lipid study of field-collected *Macoma* from Yaquina Bay. This study involved analysis of 470 individual *Macoma.* An average lipid concentration for this data set (0.38% +/- 0.16%) was provided by the researcher (D. Specht, pers. comm.).

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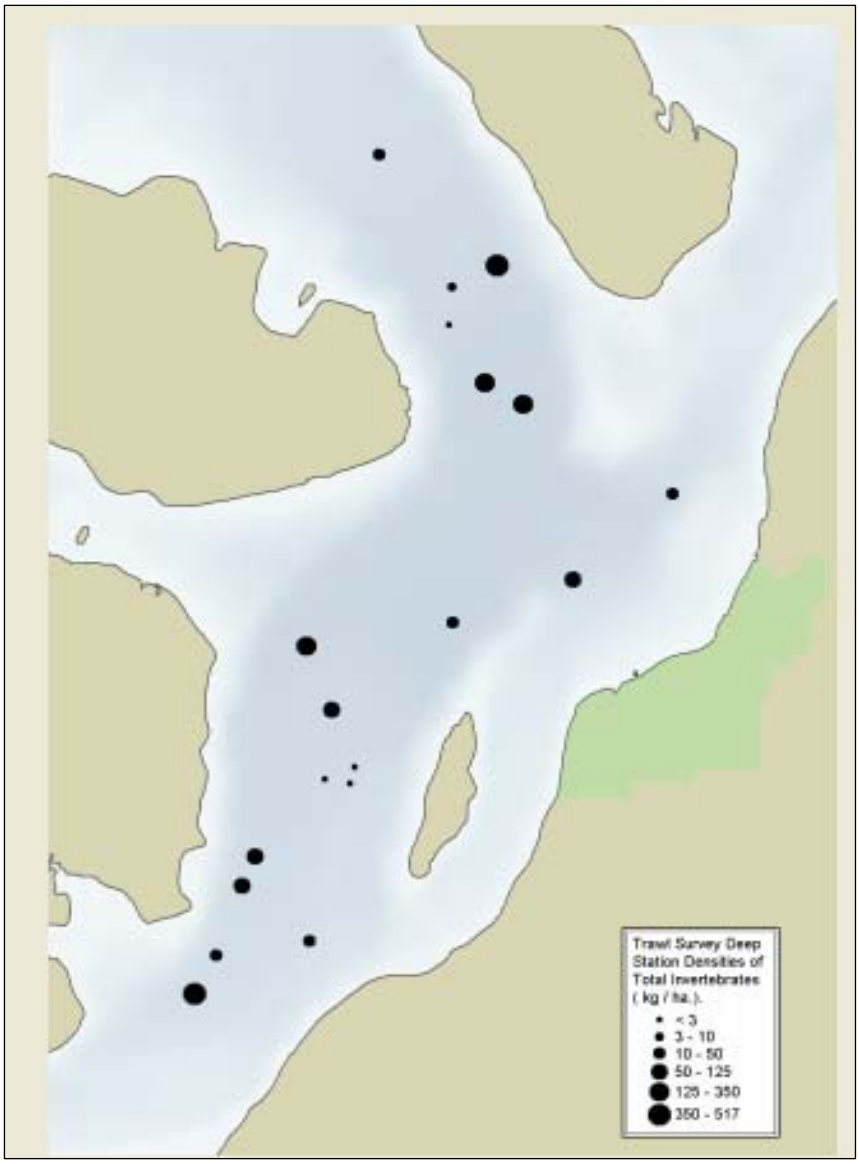

Figure A-1: WDFW Trawl Survey Data for Invertebrates from the vicinity of Anderson and Ketron Islands.

Appendix B. Information on Dungeness crab at Anderson-Ketron Island site

The following crab information was compiled and reviewed with the intent of determining Dungeness crab (Dungeness Crab) population characteristics of interest (weight, lipid content) for modeling.

Range of Dungeness crab relative to A/K site.

- Rich Childers (WDFW) was of the opinion that there was little chance for Dungeness Crab in 440 ft of water due to sparse food and no light. Depths of 100-300 ft are typically cited as the maximum depth for Dungeness Crab foraging. Dungeness Crab may go deeper in winter time.
- Wayne Palsson (WDFW) provided GIS plots of WDFW trawl data from the vicinity for crabs (Figure B-1). Total densities of male Dungeness Crab ranged from <3 kg/ha to 350 kg/ha (compilation of data from 1996-2005). Male crabs were caught in the immediate vicinity of the A/K site but densities were low (<3 kg/ha). He said that the South Sound is an exception to the rule of no crabs below 300 ft, and that they have consistently seen large Dungeness Crab deeper than 240 ft and below 360 ft since the 1990s. There are a more crabs in the vicinity of the Nisqually Reach than in other locations in South Puget Sound. This is why the Nisqually Tribe has recently started a commercial fishery there.
- Teresa Kane (WDFW) said the South Puget Sound crab fishery is not as productive as North Sound, although the Nisqually area is the most productive in South Puget Sound. She looked at a paper by Greg Jenson (who has worked with Dr. Dave Armstrong from UW) indicating that crabs have been found in depths up to 230 meters (750 ft). Crabs are moving throughout the year, molting in shallower water and getting older in deep water. Tagging studies in Port Townsend, Sequim Bays and others have indicated that crabs stay in certain bays year-round. However, residence times at particular depths are unknown. She knew of no tagging studies in South Puget Sound waters as deep as A/K. All the depth information she's collected has been in relatively shallow water (20-90 ft).
- Paul Dinnel (Shannon Pt. Laboratory) said crab movements vary with season and gender, but most activity occurs in waters shallower than at the A/K site. He cautioned that crab behavior depends on location, amount of food, bottom sediment types, and season. Generally, daily movements are between 0.3 and 0.6 miles. Tagging studies indicated an average annual movement of 5-10 miles. Females tend to stay put in shallower water for 3-4 months during breeding, while males move about 6 miles (10 km) over 6 months. However, there are some exceptions. Studies Paul conducted at Port Gardner for the Navy Homeport project found numerous female Dungeness Crab deeper than expected (as deep as 328-525 ft). Paul thought that south Puget Sound crabs stay exclusively in South Puget Sound as adults. Although there is some local

reproduction, recruitment peaks when larvae from Central and North Sound are carried by currents to South Puget Sound. Spring mating usually occurs in shallower water in 1-2 months a year. During the rest of the year, males move both vertically and horizontally.

- Dave Kendall of the Corps DMMO reviewed the PSDDA *Evaluation Procedures Technical Appendix* (EPTA) 1989 baseline trawl surveys at A/K, which included 4 seasons of crab collection in transects over the site, and stated that no crabs of harvestable size were found. Kris Phelps and Rich Childers said that there had been a commercial crab industry in this area in the early 1980's which was fished out within approx 5 years. This may partially explain the absence of crabs at A/K at the time of the EPTA study.

Characteristic Dungeness crab diet, body weight, and lipid content

- Dietary fraction of polychaetes and clams is likely to vary by food source. We consulted a summary of the literature on crab diet that was prepared by WindWard (2003) for the Lower Duwamish Superfund Phase 1 Ecological Risk Assessment. This summary indicated that polychaetes and bivalves are both significant food sources for adult crabs.
- Lipid content of hepatopancreas and edible meat were estimated from a 1991 study of PCDD/F in Dungeness Crab PTI (see Table 5 in Section 5.1.2 , main text)
- Recently-collected lipid and weight information for crabs were obtained from the Phase 2 (WindWard Consulting, 2004 and 2005) sampling of the Lower Duwamish Waterway Superfund site. The mean weight (including shell) of crabs collected was 474.4 g (n=16). Assuming that approximately 100 g is shell, we estimated that the non-shell mass of a crab was 350g. Based on a dissection of a 16.6 cm Dungeness crab by Windward in 2004, 69% of a crab (by weight) is edible meat and 31% is hepatopancreas.

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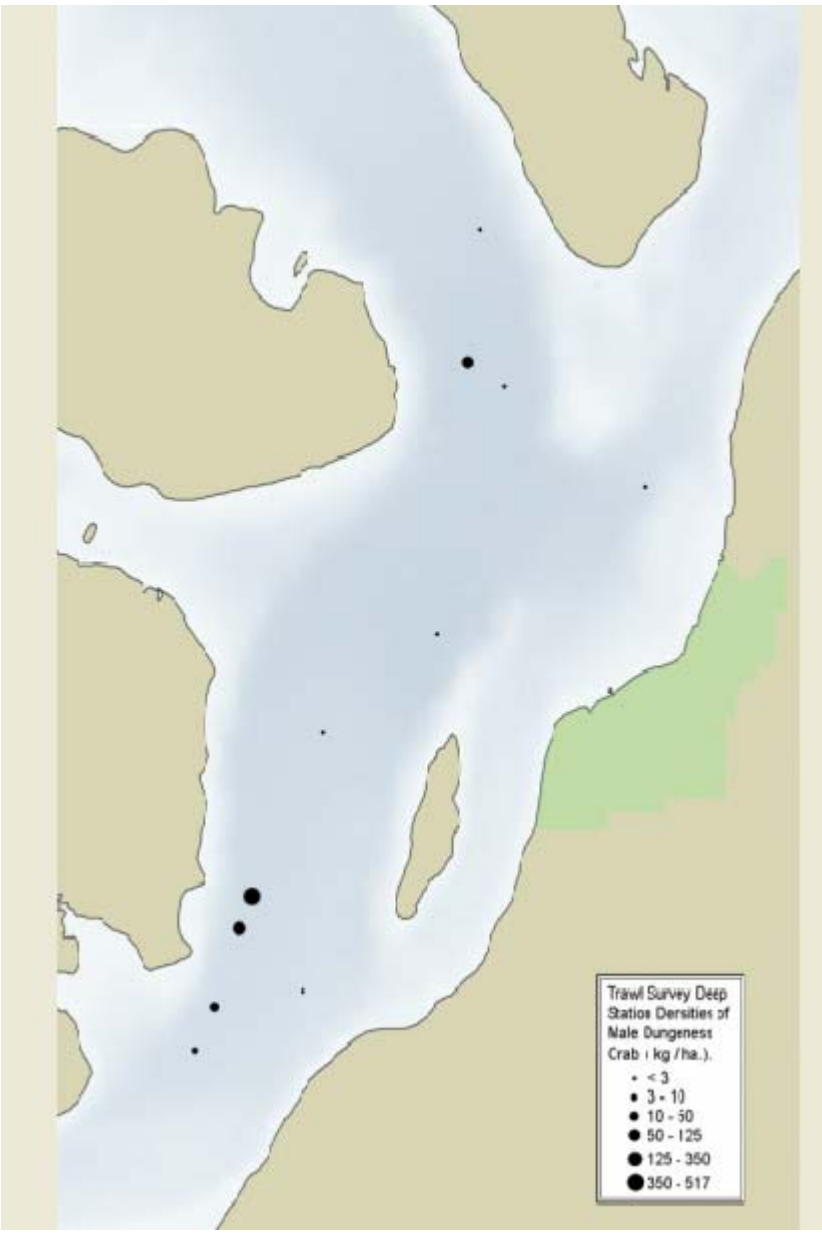

Figure B-1: WDFW Trawl Survey Data for Male Dungeness Crab from the vicinity of Anderson and Ketron Islands.

Appendix C Information on English sole at Anderson-Ketron Island Site

The following demersal fish information from the area was compiled and reviewed, with the intent of determining the English sole population characteristics of interest (weight, lipid content) for the modeling.

Range of English sole relative to the site.

- Wayne Palsson (WDFW) said that there could definitely be English sole (English Sole) at the A/K site since they have been observed all over Puget Sound at every depth sampled. He provided a table which showed that rat fish (60.7% weight of total catch) and English sole (13.2% weight of total catch) comprise the majority of all fish species caught in deep water trawling in South Puget Sound (Table C-1). He also provided WDFW trawl data for all fish and for English sole from the vicinity of the A/K site (Figures C-1 and C-2). Total densities of English Sole ranged from <280 kg/ha to 1025 kg/ha (compilation of data from 1987-2005). English Sole were caught in the immediate vicinity of the A/K site at densities of <280 – 535 kg/ha. Based on the figure he provided there does not appear to be a significant difference in the density of English Sole between different deep water trawling locations in the A/K environs. Based on this information, we assumed that the relative productivity of the deep-water benthic environments in this area are approximately equal.

- Wayne said that little is known about home range and daily feeding activities of English Sole. He declined to provide a best-professional-judgment on the percentage of time that an English sole would spend in an area/depth represented by the A/K site. However, he indicated that earlier studies (Betsy Day, 1976, and a 1960's UW PhD dissertation) showed that some populations of English sole (including South Puget Sound) have affinities for basins and may "home" there. English Sole appear to have gender-specific associations with certain types of sediment substrate.

- Sandie O'Neill (WDFW) along with Mark Meyers and Mary Mosier (both of NOAA) have been conducting the only tagging study of English Sole in Puget Sound (Eagle Harbor). Sandy emphasized that English Sole movement is really made up of three types of movement: seasonal, home range within a season; and diel movements.

    - Seasonal. Sandie's Eagle Harbor tagging data show that English Sole are generally in shallow Central Puget Sound waters in spring and summer and start leaving for deeper waters in early fall to winter for spawning. However she has seen considerable variation among individuals in this annual pattern and has identified resident and transient fish that

completely violate this pattern. She said it would be reasonable to assume that a fish spends 5 months of the year in a specific area and, given the depth of the A/K environs, she would assume that English sole would be there in greater numbers during the spawning season. One of Sandy's colleagues did a compilation of old tagging data from Puget Sound, Canada and the coast of Washington; this indicates that, for South Puget Sound, 6 female English Sole caught in 1942 migrated 6-9 nautical miles. Based on her knowledge of the literature, Sandy thought that annual migrations of English Sole would not exceed 10 nautical miles.

- Home range within a season. Sandy thought a good estimate of day-to-day movement based on tagging studies would be 1-2 km.
- Diel movement. English Sole are in deeper waters during the day and shallower waters at night. There are no definitive data on feeding, but this pattern suggests that they are likely feeding at night in shallow water.

Characteristic English sole weight and lipid content

- Recently collected lipid and weight information for English Sole were obtained from the Phase 2 (2004 and 2005) sampling of the Lower Duwamish Waterway (LDW) Superfund site. While there are other sources of information on English Sole, much of these are for fillets rather than whole body. The average English sole lipid and weight in the Phase 2 data was 5.16 % wet weight and 199.1g (n=44).
- Due to time constraints, we were unable to conduct a comprehensive review of the literature to determine the percentage representation of polychaetes and clams in an adult English sole's diet in South Puget Sound. However, we were able to review a summary of the literature on English sole diet that was prepared by Windward, Inc., for the Lower Duwamish Superfund Phase 1 Ecological Risk Assessment (WindWard Consulting, 2003). This summary indicated that polychaetes and bivalves both represent a significant food source for adult English Sole.

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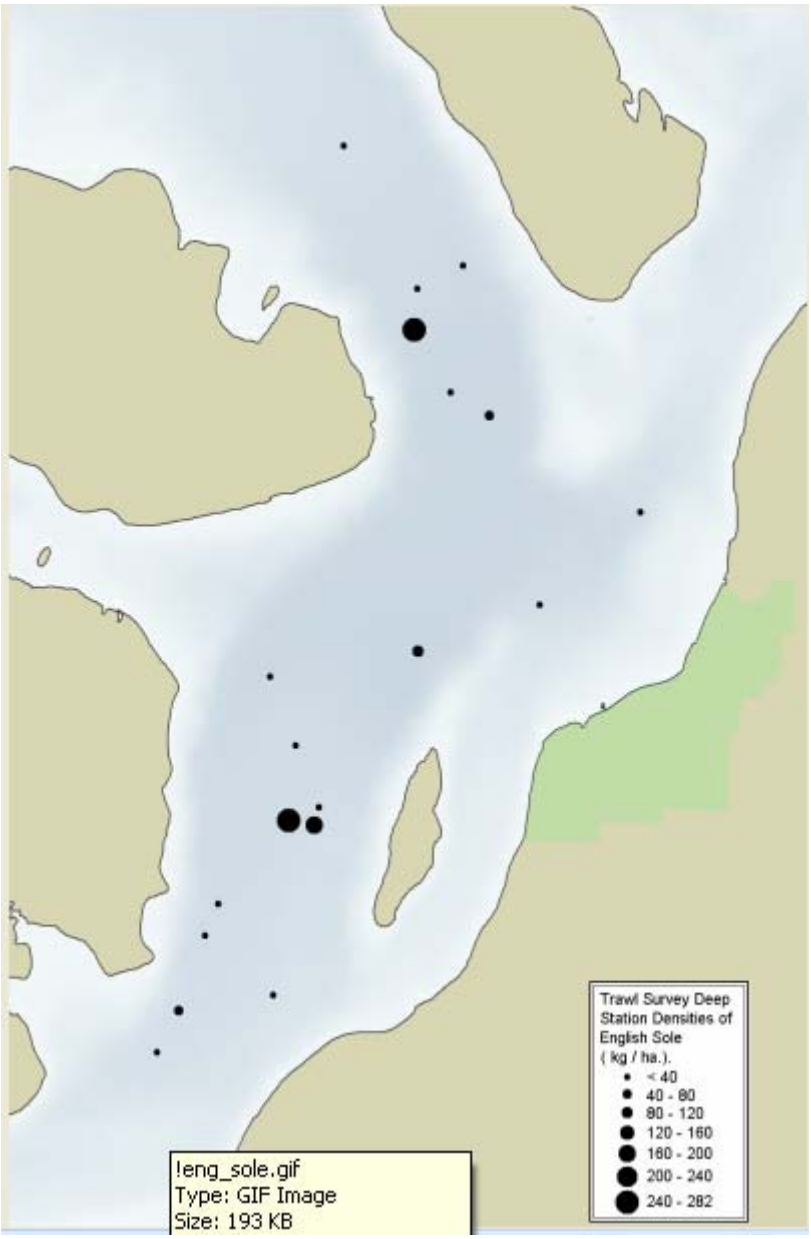


Figure C-1: WDFW Trawl Survey Data for English Sole caught in the vicinity of Anderson and Ketron Islands.

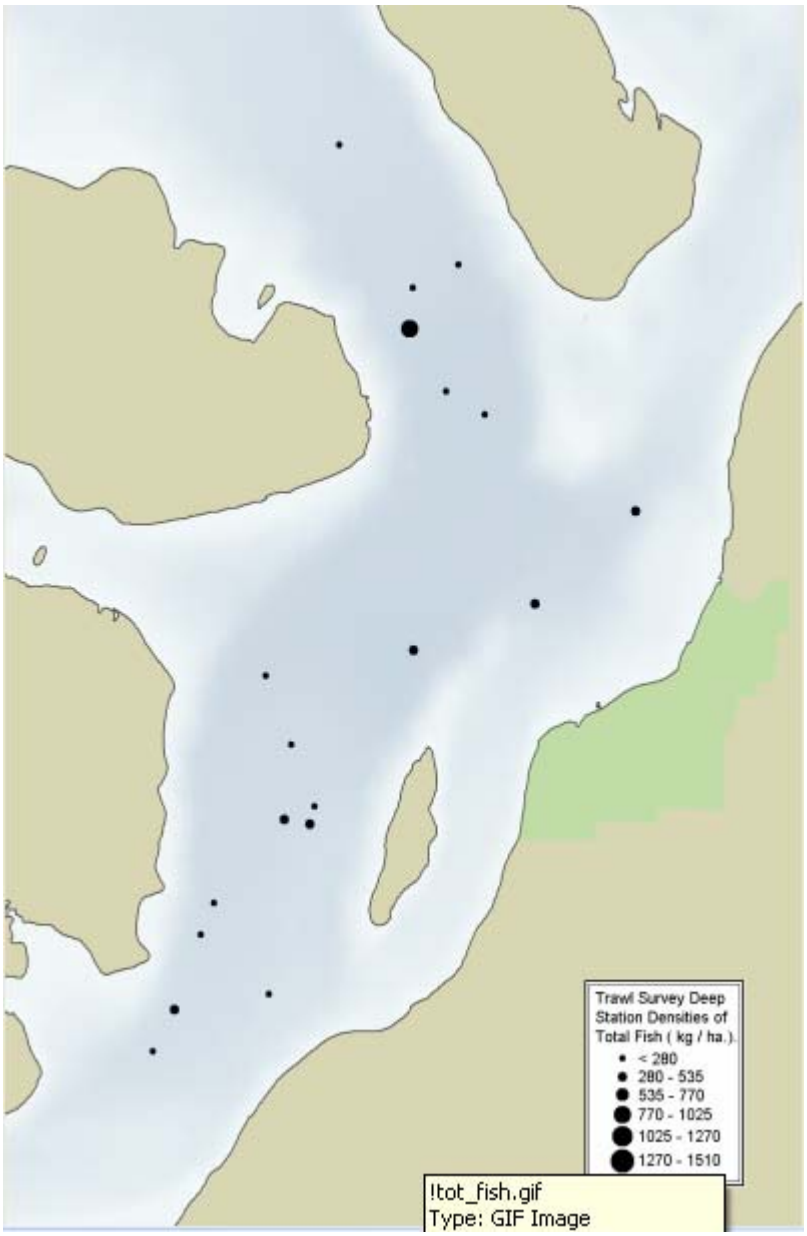


Figure C-2: WDFW Trawl Survey Data for Total Fish caught in the vicinity of Anderson and Ketron Islands.

Table C-1: Average Percent Weight of Species from Bottom Trawl in Waters >60 fms in South Puget Sound

Source: Wayne Palsson, WDFW, 10 Feb 2006

TAXON	NAME	Average	TAXON	NAME	Average
8105010101	BANANA STARFISH	15.0	8716020101	SPOTTED RATFISH	60.7
3760060104	GIGANTIC ANEMONE	12.8	8857041512	ENGLISH SOLE	13.2
8117031201	SUNFLOWER STAR	8.4	8710010201	SPINY DOGFISH	5.2
8117030501	PINK SHORT SPINED SEASTAR	7.6	8793010801	BLACKBELLY EELPOUT	5.1
8175020101	RED SEA CUCUMBER	7.1	8791030601	PACIFIC TOMCOD	2.1
8179010101	SWEET POTATO SEA CUCUMBER	4.2	8857041201	DOVER SOLE	1.9
	DUNGENESS CRAB (MALE)	3.7	8713040108	LONGNOSE SKATE	1.6
6188030104	DUNGENESS CRAB (FEMALE)	3.5	8857040403	SLENDER SOLE	1.4
6179180101	ALASKAN PINK SHRIMP	3.4	8857040802	NORTHERN ROCK SOLE	1.4
8149030201	GREEN SEA URCHIN	3.4	8791040102	PACIFIC WHITING (HAKE)	1.2
3760060100	METRIDIUM UNIDEN.	3.0	8826010103	BROWN ROCKFISH	0.9
5134010102	ROSY TRITONIA	2.8	8857030101	PACIFIC SANDDAB	0.8
8111040501	VERMILION STAR	2.3	8783010101	PLAINFIN MIDSHIPMAN	0.7
	RED ROCK CRAB (MALE)	2.1	8826010120	QUILLBACK ROCKFISH	0.7
	RED ROCK CRAB (MIXED)	1.9	8857041401	STARRY FLOUNDER	0.5
8162040103	HEART URCHIN	1.8	8857043501	REX SOLE	0.4
	GRACEFUL CRAB (MALE)	1.8	8791030401	PACIFIC COD	0.3
8113010301	MORNING SUN STAR	1.7	8791030701	WALLEYE POLLOCK	0.3
8114030101	LEATHER STAR	1.4	8857040803	SOUTHERN ROCK SOLE	0.2
5707030301	BIG RED SQUID	1.4	8831081301	BLACKTIP POACHER	0.2
6188030101	RED ROCK CRAB (FEMALE)	1.3	8705020101	SIXGILL SHARK	0.2
8117030302	FALSE OCHRE STAR	1.3	8831021801	PACIFIC STAGHORN SCULPIN	0.1
5515470201	BUTTER CLAM	1.2	8831024001	ROUGHBACK SCULPIN	0.1
6179050101	KRILL UNIDEN.	1.2	8713040103	BIG SKATE	0.1
8111040403	SPINY VERMILION STAR	0.8	8831021001	BUFFALO SCULPIN	0.1
5509050102	PINK SCALLOP (SMOOTH)	0.8	8857041601	C-O SOLE	0.1
6188030105	GRACEFUL CRAB (FEMALE)	0.7	8831022204	GREAT SCULPIN	0.1
8113010103	ROSE SEA STAR	0.6	8708010101	BROWN CAT SHARK	0.1
8117031001	LONG ARMED SPINY SEASTAR	0.5	8826010108	COPPER ROCKFISH	0.1
8113010304	STIMPSON'S SUN STARFISH	0.4	8747010201	PACIFIC HERRING	0.1
6179180107	DOCK SHRIMP	0.4	6179180105	SPOTTED PRAWN	0.1
5103780101	OREGON HAIRY TRITON	0.3			
3760020101	MOTTLED ORANGE ANEMONE	0.2			
6179180204	SIDESTRIPED SHRIMP	0.2			
5708010203	LITTLE RED OCTOPUS	0.1			
	GRACEFUL CRAB (MIXED)	0.1			
5103760406	MOON SNAIL	0.1			

Appendix D. Analysis of Tulalip Tribe Puget Sound Crab and Bottom Fish Consumption Rates

Introduction

In order to evaluate risks posed by consumption of contaminants in seafood associated with a DMMP disposal site, it was deemed necessary to develop consumption rates for seafood that might accumulate site related contaminants. Given that the site is 460 feet below the surface of Puget Sound, it was decided that crabs and bottom fish were the seafood types that might accumulate site related contaminants. Tribal consumption of bottom fish and crabs was selected for development of site related seafood consumption risk estimates. This memo discusses the approach for derivation of relevant consumption rates. Appropriate values for exposure frequency, exposure duration, and body weight parameters are presented in the discussion/recommendations section at the end of this memo.

Methods

Crab and bottom fish consumption rate data from the Tulalip Tribes (Toy et al. 1996) were used for this analysis. Based on recommendations in Risk Assessment Guidance for Superfund (EPA 1989), consumer only 95th percentile seafood consumption rates were selected for risk analysis. The fraction of seafood harvested from Puget Sound was used as the fraction of seafood that might be affected by the site.

Consumer-only 95th percentile consumption rates for Puget Sound harvested seafood were derived using two approaches:

1. Separate 95th percentile crab and bottom fish consumption rates.
2. Integrated 95th percentile crab and bottom fish consumption rate with separate crab and bottom fish rates being developed by multiplying the overall consumption rate by the ratio of:
    a. Average crab consumption rate / (average crab consumption rate + average bottom fish consumption rate)
    b. Average bottom fish consumption rate / (average crab consumption rate + average bottom fish consumption rate)

The integrated approach was developed in order to address conservatism that might result from summing the 95th percentile crab and bottom fish ingestion rates.

The separate crab/bottom fish approach involved the following steps.

1. Determine the crab and bottom fish consumption rates (g/day) for each individual:
    a. Crab rate = (ingestion rate for Dungeness Crab + ingestion rate for Red Rock Crab) x fraction shellfish harvested from Puget Sound x individual body weight
    b. Bottom fish rate = ingestion rate for bottom fish x fraction bottom fish harvested from Puget Sound x individual body weight

2. For the crab and bottom fish data sets, remove all individuals with no crab or bottom fish consumption.
3. Rank order the values from lowest to highest for the crab and bottom fish data sets.
4. Use Excel's percentile function to derive the 95th percentile consumption rates for crab and bottom fish data sets.

The integrated crab/bottom fish approach involved the following steps:

1. Determine the integrated consumption rate (g/day) for each individual: ((ingestion rate for Dungeness Crab + ingestion rate for Red Rock Crab) x fraction shellfish harvested from Puget Sound + ingestion rate for bottom fish x fraction bottom fish harvested from Puget Sound) x individual body weight
2. Remove all individuals with no crab/bottom fish consumption
3. Rank order the values from lowest to highest
4. Use Excel's percentile function to derive the 95th percentile.
5. Use relative ingestion rates of crab and bottom fish to partition the overall ingestion rate into separate crab and bottom fish consumption rates (SEE 1st paragraph in the Methods section).

Results

Table 1: Crab Consumption Rate

Percentile	Ingestion Rate (g/day)
10%	1.2
15%	1.5
20%	1.8
25%	2.3
30%	2.7
35%	4.2
40%	4.6
45%	5.0
50%	6.7
55%	7.6
60%	9.2
65%	11.1
70%	11.9
75%	15.8
80%	18.5
85%	22.0
90%	33.8
95%	93.7
99%	117.5

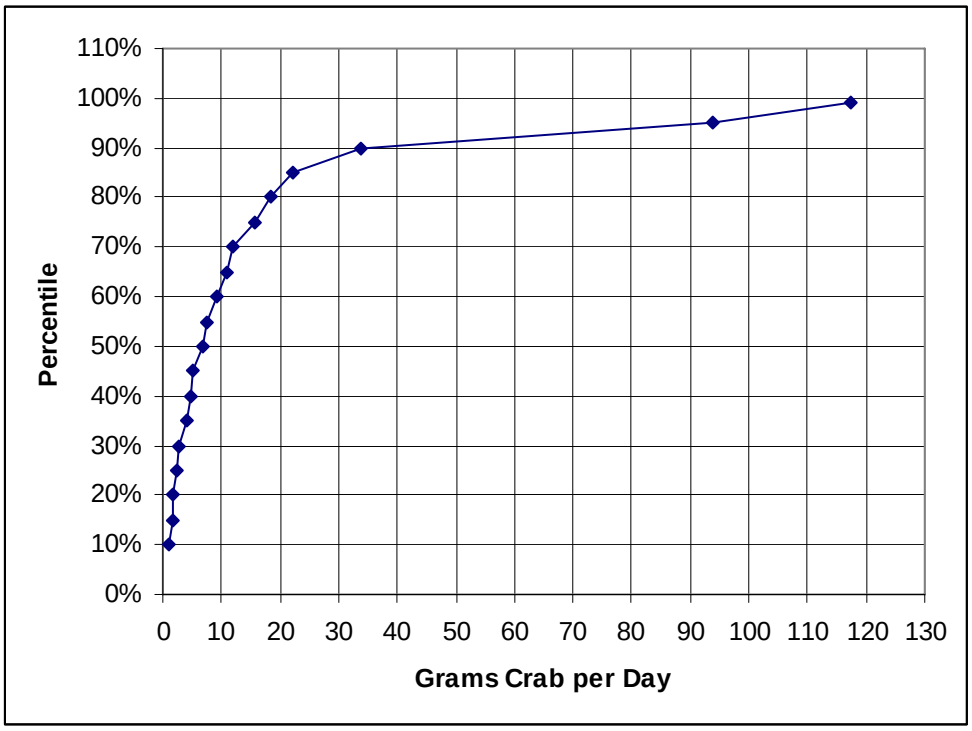


Figure D1: Crab consumption rate

Table D2: Bottom Fish Consumption Rate	
Percentile	Ingestion Rate, (g/day)
10%	0.8
15%	0.8
20%	1.1
25%	1.2
30%	1.3
35%	1.6
40%	1.8
45%	1.9
50%	1.9
55%	2.2
60%	2.9
65%	3.1
70%	3.4
75%	4.8
80%	6.5
85%	8.7
90%	10.4
95%	11.1
99%	14.1

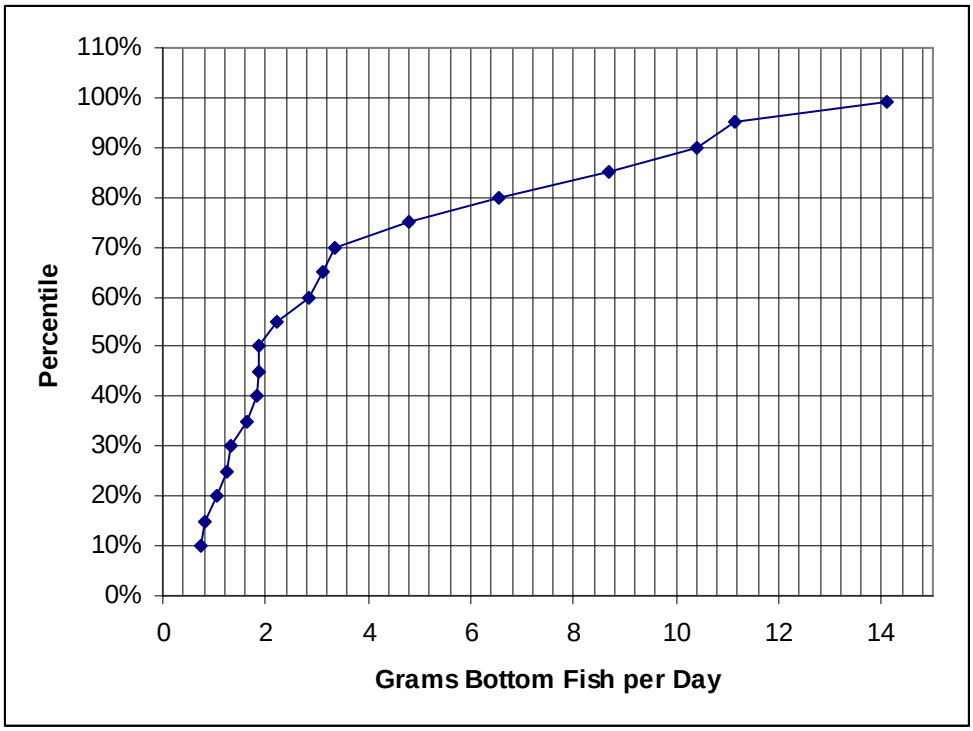


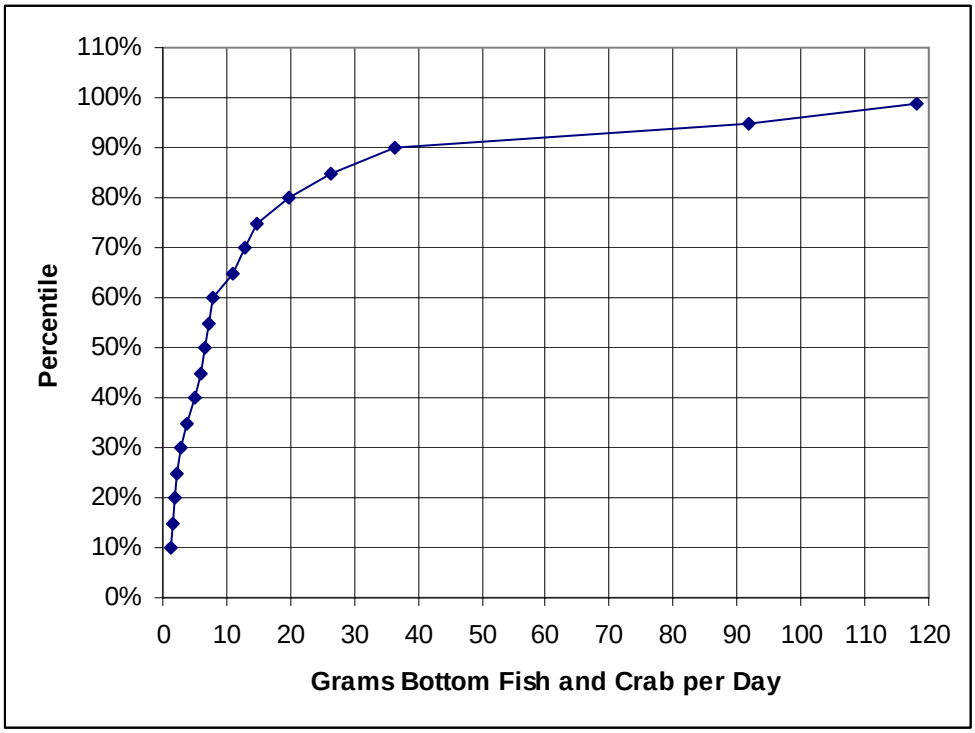
Figure D2: Bottom fish consumption rate

Table D3: Integrated bottom fish and crab consumption rates partitioned into separate crab and bottom fish consumption rates using relative crab and bottom fish ingestion rates

		Consumption rate for:	
		Crab % of IR = 89.7	Bottom fish % of IR = 10.3
Percentile	Integrated Consumption (g/day)	Crab g/day	Bottom fish g/day
10%	1.4	1.3	0.1
15%	1.5	1.4	0.2
20%	1.9	1.7	0.2
25%	2.1	1.9	0.2
30%	2.9	2.6	0.3
35%	3.6	3.2	0.4
40%	4.9	4.4	0.5
45%	5.8	5.2	0.6
50%	6.5	5.8	0.7
55%	7.2	6.5	0.7
60%	8.0	7.1	0.8
65%	10.9	9.8	1.1
70%	12.8	11.5	1.3
75%	14.8	13.3	1.5
80%	19.8	17.8	2.0

Table D3: Integrated bottom fish and crab consumption rates partitioned into separate crab and bottom fish consumption rates using relative crab and bottom fish ingestion rates			
		Consumption rate for:	
		Crab % of IR = 89.7	Bottom fish % of IR = 10.3
Percentile	Integrated Consumption (g/day)	Crab g/day	Bottom fish g/day
85%	26.4	23.7	2.7
90%	36.4	32.6	3.8
95%	91.8	82.3	9.5
99%	118.1	105.9	12.2

Figure D3



Discussion/Recommendations

The 95th percentile, consumer only, Puget Sound harvested consumption rates are given in Table 4.

Table D4: Recommended Crab and Bottom fish Consumption Rates

	95th Percentile Rate (g/day) for:	
Approach	Crab	Bottom fish
Separate crab/bottom fish ingestion rates	93.7	11.1
Integrated crab/bottom fish ingestion rates	82.3	9.5

It is recommended that the average adult body weight for Tulalip Tribes participants as derived in Toy et al. 1996 be used. This value is 81.8 kg.

With regards to exposure frequency, the consumption rates derived for the Toy et al. study are in terms of grams per day on a yearly basis. Consequently, the exposure frequency value should be set at 52 weeks per year or 365 days per year.

Given that members of seafood consuming tribes may consume seafood throughout their lives and that tribal members may relocate over limited distances and still utilize the same areas for seafood harvest, it is recommended that the exposure duration be set at 70 years.

References

Toy, KA, NL Polissar, S Liao, and GD Mittelstaedt. 1996. A Fish Consumption Study of the Tulalip and Squaxin Island Tribes of the Puget Sound Region

U.S. EPA. 1989. Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A), Interim Final. Office of Solid Waste and Emergency Response, Office of Research and Development, EPA/540/1-89/2002

Appendix E. Derivations of Values Used to Model PCDD/F in English Sole

Selection of sediment to clam biota-sediment accumulation factors (BSAFs) for modeling English sole

The Gobas steady state trophic model uses a BSAF approach to estimate the tissue concentration of PCDD/F in benthic organisms. A BSAF is the expression of the concentration of contaminant in an organism (normalized to the organism's lipid fraction) relative to the concentration of contaminant in the sediment to which the organism is exposed (normalized to the organic carbon content of the sediment). In trophic trace, the standard equation for a BSAF is modified to solve for the concentration in the benthic organism as follows:

$$C_B = C_S * (f_L / f_{OC}) * BSAF$$

where

C_B = concentration of contaminant in biota, mg/kg wet weight
f_L = the fraction lipid of the biota, kg lipid/kg wet weight
C_S = the concentration of contaminant in sediment, mg/kg dry weight
f_{OC} = the fraction organic carbon in sediment, kg organic carbon/kg dry weight
BSAF = biota-sediment accumulation factor (unitless)

We reviewed the literature to identify BSAF information specific to PCDD/F in benthos. Marine benthic (Trophic level 1) BSAF means and 95th confidence limits on the mean were reported by Clarke and McFarland (2004) for PCDD/F congeners. We used the congener-specific BSAF mean values, adjusted based on the congener distribution in sediments from the 2005 Anderson-Ketron site monitoring data. The specific BSAF thus derived was 0.61 (see Table E1).

Estimation of TEQ-weighted K_{ow} and K_{oc} for the English .

TrophicTrace requires both octanol-water partitioning (K_{ow}) and organic carbon-water partitioning (K_{oc}) coefficients to calculate exposure via water. Table E-2 shows the approach used to calculate these two values considering the congener distribution in sediments from the 2005 Anderson-Ketron site monitoring data. The specific K_{ow} and K_{oc} values calculated were 6.31 and 5.91, respectively.

Table E1. Development of a mean weighted BSAF for sediment to clam using congener distributions from A/K site data

Congener	**Mean BSAF from McFarland & Clarke (2004)**	**A-K Percent Total TEQ**	**Weighted Mean BSAF = % TEQ x Mean BSAF**
2,3,7,8-TCDD	0.433	0.043	0.019
1,2,3,7,8-PeCDD	1.128	0.181	0.204
1,2,3,4,7,8-HxCDD	1.283	0.080	0.102
1,2,3,6,7,8-HxCDD	0.211	0.089	0.019
1,2,3,7,8,9-HxCDD	0.514	0.049	0.025
1,2,3,4,6,7,8-HpCDD	0.05	0.122	0.006
OCDD	0.039	0.009	0.000
2,3,7,8-TCDF	0.899	0.044	0.039
1,2,3,7,8-PeCDF	1.093	0.015	0.016
2,3,4,7,8-PeCDF	0.55	0.203	0.111
1,2,3,4,7,8-HxCDF	0.288	0.070	0.020
1,2,3,6,7,8-HxCDF	1.105	0.026	0.029
1,2,3,7,8,9-HxCDF	0.623	0.024	0.015
2,3,4,6,7,8-HxCDF	0.463	0.013	0.006
1,2,3,4,6,7,8-HpCDF	0.032	0.030	0.001
1,2,3,4,7,8,9-HpCDF	0.252	0.002	0.001
OCDF	0.033	0.001	0.000
Average Weighted BSAF			**0.614**

Table E2: Development of a weighted Log Kow and Log Koc clam using congener distributions from A/K site data

	WHO TEF	A-K Percent Total TEQ	Congener Log Kow [a]	Antilog log Kow = Kow	Congener-weighted log Kow	Congener - weighted Koc
2,3,7,8-TCDD	1	0.042967802	6.8	6309573.445	271108.5003	
1,2,3,7,8-PeCDD [b]	1	0.181212374	7.4	25118864.32	4551849.029	
1,2,3,4,7,8-HxCDD	0.1	0.079650691	7.8	63095734.45	5025618.817	
1,2,3,6,7,8-HxCDD	0.1	0.088819454	7.8 [c]	63095734.45	5604128.657	
1,2,3,7,8,9-HxCDD	0.1	0.049458032	7.8	63095734.45	3120590.857	
1,2,3,4,6,7,8-HpCDD	0.01	0.121513539	8	100000000	12151353.87	
OCDD	0.0001	0.008581022	8.2	158489319.2	1360000.312	
2.3.7.8-TCDF	0.1	0.043890947	6.1	1258925.412	55255.42878	
1,2,3,7,8-PeCDF	0.05	0.01476641	6.5	3162277.66	46695.48998	
2,3,4,7,8-PeCDF [d]	0.5	0.20268452	6.5	3162277.66	640944.729	
1,2,3,4,7,8-HxCDF	0.1	0.070133985	7	10000000	701339.8462	
1,2,3,6,7,8-HxCDF	0.1	0.025871585	7	10000000	258715.8497	
2,3,4,6,7,8-HxCDF	0.1	0.024246285	7	10000000	242462.8457	
1,2,3,7,8,9-HxCDF	0.1	0.012571393	7 [c]	10000000	125713.9293	
1,2,3,4,6,7,8-HpCDF	0.01	0.030490447	7.4	25118864.32	765885.4092	
1,2,3,4,7,8,9-HpCDF	0.01	0.002344382	7.4	25118864.32	58888.21811	
OCDF	0.0001	0.000797134	8	100000000	79713.3829	
Average		1.000			2062368.539	
Log Average					**6.314366275**	**5.9105612** [d]

a – Log Kow from Yunker & Cretney (2000) referencing McKay (1992)
b – Yellow highlighted cells are principal contributors to toxicity at this site.
c – These values were not in Yunker and Cretney (2000), but were interpolated from adjacent congeners' Kow's
d – This is from the equation log Koc = 0.937 (log Kow) - 0.006.

Estimation of Fish Uptake and Elimination Kinetics

The model used to estimate fish and crab body burdens for hydrophobic organic compounds relies on a steady-state uptake model based on the approach of Gobas (1993 and 1995):

$$C_f = \frac{k_1 * C_{wd} + k_d * C_{diet}}{k_2 + k_e + k_m + k_g}$$

Where:

k_1 = gill uptake rate (L/Kg/d)
C_{wd} = freely dissolved concentration in water (ng/L)
k_d = dietary uptake rate (d^{-1})
C_{diet} = concentration in the diet (μg/kg)
k_2 = gill elimination rate (d^{-1})
k_e = fecal egestion rate (d^{-1})
k_m = metabolic rate (d^{-1})[20]
k_g = growth rate (d^{-1})
C_f = concentration in fish (μg/kg)

Several sources provide equations for the uptake and elimination rate constants (k_2, k_e, k_m and k_g); these are described in greater detail in Gobas (1993) and von Stackelberg et al. (2002) and shown in Table E3 (below).

Table E3. Uptake Rate Constants for Fish

Gill uptake rate constant	$k_1 = 1/((V_F/Q_W) + (V_F/Q_L)/K_{ow})$
Gill elimination rate constant	$k_2 = 1/((V_L/Q_w)*K_{ow} + (V_L/Q_L)$
Metabolic transformation rate constant	$k_m=0$
Dietary uptake rate constant	$k_d= E_{D*}F_D/V_F$
Fecal egestion rate constant	$k_e = 0.4*F_{D*}E_{D*}K_{GF}/V_F$

Where:

V_F = fish weight (kg)
V_L = lipid weight of fish (kg)
Q_W = aqueous phase gill uptake transport rate (L/d) = $88.31*VF^{0.6}$
Q_L = lipid phase gill uptake transport rate (L/d) = Qw/100
E_D = dietary uptake efficiency (unitless)

[20]Metabolism of the chemical in question (k_m) is assumed to be zero in Trophic Trace.

F_D = food ingestion rate (kg/d) = $0.022*V_F^{0.85}*e^{0.06Tw}$
T_w = water temperature (degrees C)
K_{GF} = gut-to fish partition coefficient (unitless) = $0.5*L_D/L_F$
L_F = lipid content of fish (kg lipid/kg)
L_D = lipid content of food (kg lipid/kg)
K_{ow} = octanol-water partitioning coefficient

Table E4 shows the uptake and elimination rate constants calculated for English sole using the Puget Sound and Anderson/Ketron Disposal Site-specific information provided in Table 3 of the main memo (e.g., fish weight, fish lipid content, benthic prey organism lipid content, water temperature) applied to the equations in Table E3.

Table E4. Uptake and Elimination Rate Constants Calculated by TrophicTrace for Fish at the A/K Disposal site

Fish	Chemical	Qw	Ql	k1	k2	kd	ke	kg
English Sole:	PCDD/F	33.5	0.34	168	0.0016	0.025	0.0050	0.014

References

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